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# Design of a SEPIC Based Hybrid Energy System with a New Rectifier Stage Topology

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**Abstract:** Among Alternate energy sources solar photovoltaic and fuel cellenergy have being popular ones in recent research owing to generous, ease of availability, free to access and simple standard mechanism for convertibility to the electric energywith help of simple converter structure. This paper represents the realization of a hybrid energy system for a residential stand-alone application. This work presents a new system topology of the front-end rectifier stage for a fuel cell and photovoltaic (PV) energy system. This proposed circuit allows the two sources to fulfill the load demand separately or concurrently depending on the availability of the input sources. The built-in nature of this Cuk - SEPIC (Single Ended Primary Inductance Converter) based converter does not require input filters for filtering the high frequency harmonics.

**Key words:** Hybrid Energy Sources · Cuk converter · SEPIC converter · Harmonics

## INTRODUCTION

Environment friendly non-hazardous solutions are becoming more eye-catching than ever in this current scenario because of severe pollutions and global warming. Due to the increase in developing technology, demand for large amount of energy makes us to seek for new alternate energy sources [1-4]. The most leading non pollutant Source field is renewable energy sources.Natural sources for generating electricity have been rapidly depleting and environmental impacts made by the conventional sources are very much threading for the modern world. The demand of the electricity is going in a rapid manner and always a gap exists between the supply and the generation. Any country that can reduce or even nullify this gap will be the super power in future. All the countries are hardly working towards this goal for bringing the corresponding developed countries or developing one to the surplus one in energy sector [5, 6]. We are in this extreme compulsion to think about the alternate energy sources, which is going to generate enough power for the future generation. Among alternate sources other than hydro and wind power, the fuel celland photovoltaic energy holds the necessary potential to meet our energy demands and also the recent research attractive areas [7-10]. Fuel cell energy is capable of generatinga required power from the chemical reaction and it is available in all the time [9, 10]. But its cost is really highwhile we go for a large scale system. Similarly, solar energy is present throughout the day but the solar irradiation levels vary due to sun intensity and unpredictable shadows cast by clouds, birds, trees and other disturbances. The common inherent drawback of solar PV systems is their intermittent natures that make them unreliable.

However, by combining these two intermittent sources with suitable circuit topology and by incorporating maximum power point tracking (MPPT) algorithms for solar PV system and fuel cell systems, the system's power transfer efficiency and reliability can beimproved significantly. When a source is unavailable or insufficient in meeting the load demands, the other energy source can compensate for the difference [7, 10].

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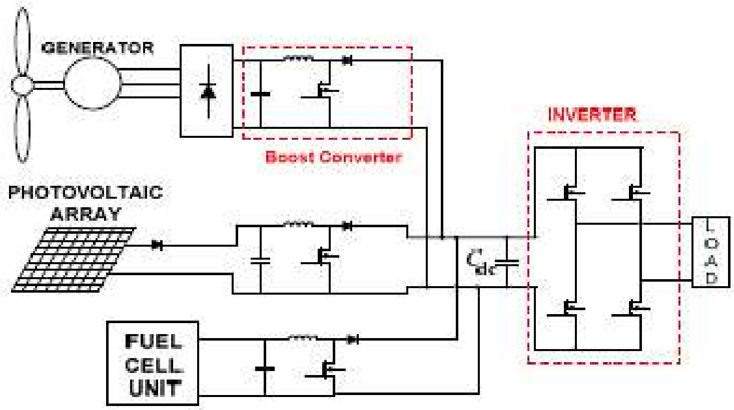


Fig. 1: Hybrid system with multi-connected boost converter

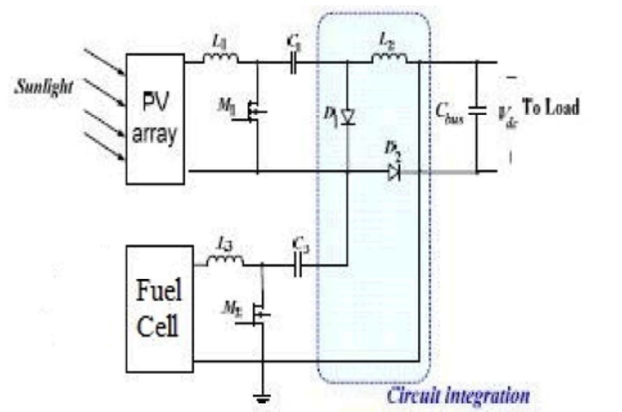


Fig. 2: Proposed system for a Hybrid Fuel cell/PV system

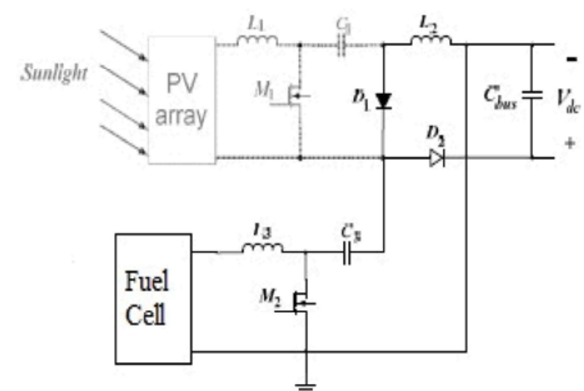


Fig. 3: Only Fuel cell source is operational (SEPIC)

Several hybrid fuel cell/PV and wind/PV power systems with MPPT control have been proposed and discussed in works [1- 5].Most of the systems in literature use a separate DC/DC boost converter connected in parallel in the rectifier stage as shown in Figure 1 to perform the MPPT control for each of the renewable energy power sources [1- 4].A simpler multi input structure has been suggested by [5] that combine the sources from the DC-end while still achieving MPPT for each renewable source. The structure proposed by [5] is a coalition of the buck and buck-boost converter.

In this paper, an alternative multi-input rectifier structure is proposed for hybrid fuel cell/solar energy systems. The proposed design is a coalition of the Cuk and SEPIC converters. The features of the proposed topology are: 1) the inherent nature of these two converters eliminates the need for separate input filters and the complex design circuit. [7, 8]; 2) It can support for wide range of input variation; 3) MPPT can be applied for each source; 4) individual and simultaneous operation is supported.

**Proposed M ulti-Input Rectifier Stage Topology:** A system diagram of the proposed rectifier stage of a hybrid energy system is shown in Figure.2. Where one of the inputs is connected to the output of the solar PV array and the other input connected to the output of a Fuel cell system. The coalition of the two converters is achieved by reconfiguring the two existing diodes from each converter and the shared utilization of 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. Figure.3. illustrates the case when only the Fuel cell energy source is available. In this case, D1 turns off and D2 turns on; the proposed circuit becomes a SEPIC converter. On the other hand, if only the PV source is available, then D2 turns off and D1 will always be on and the circuit becomes a Cukconverter as shown in Figure.4. In both cases, both SEPIC and CUK converters have buck/boost capability, which provide more design flexibility in the system while duty ratio control is utilized to perform MPPT control.

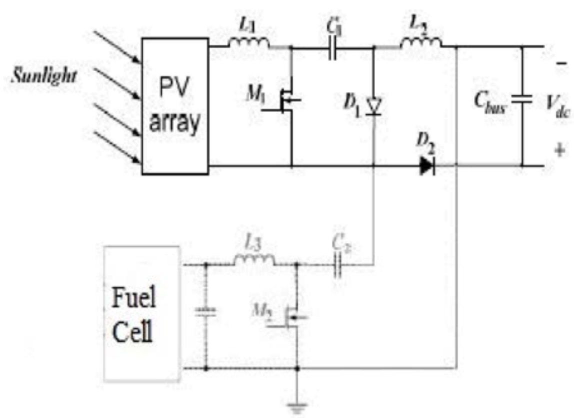


Fig. 4: Only PV source is operation (Cuk)

If only fuel cell source is in operational condition means the proposed circuit will be acted as a SEPIC converter at the same time if PV array alone in operational condition means the circuit will be treated as a Cuk converter. But in both cases the step up and step down operation may possible.Incremental conductance algorithm is implemented for drawing maximum power from the solar and fuel cell energy sources. This method is quit common among all the other types and also it is extracting more power from the targeted source.

**Modes of Operation:**

*State I ($M_1$ on, $M_2$ on):*

$$i_{L1} = I_{i,PV} + \frac{V_{PV}}{L_1}t \qquad 0 < t < d_1T_s$$

$$i_{L2} = I_{dc} + \left(\frac{v_{c1} + v_{c2}}{L_2}\right)t \qquad 0 < t < d_1T_s$$

$$i_{L3} = I_{i,W} + \frac{V_W}{L_3}t \qquad 0 < t < d_1T_s$$

*State III ($M_1$ off, $M_2$ on):*

$$i_{L1} = I_{i,PV} + \left(\frac{V_{PV} - v_{c1}}{L_1}\right)t \qquad d_1T_s < t < d_2T_s$$

The modes of operation are discussed in an analytical way for easy understanding and simplification purpose. Because of ON and OFF functioning of switching elements and corresponding un-controlled semi conducting devices the different types of modes of operations are possible.

$$i_{L2} = I_{dc} + \frac{v_{c2}}{L_2}t \qquad d_1T_s < t < d_2T_s$$

$$i_{L3} = I_{i,W} + \frac{V_W}{L_3}t \qquad d_1T_s < t < d_2T_s$$

*State IV ($M_1$ off, $M_2$ off):*

$$i_{L1} = I_{i,PV} + \left(\frac{V_{PV} - v_{c1}}{L_1}\right)t \qquad d_2T_s < t < T_s$$

$$i_{L2} = I_{dc} - \frac{V_{dc}}{L_2}t \qquad d_2T_s < t < T_s$$

$$i_{L3} = I_{i,W} + \left(\frac{V_W - v_{c2} - V_{dc}}{L_3}\right)t \qquad d_2T_s < t < T_s$$

**Simulation Results:** In this section, simulation results from PSIM 8.0.7 is given to verify that the proposed multi-input rectifier stage can support individual as well as simultaneous operation. The following Fig.5 and Fig.6 expresses the Output voltage of proposed model with filter circuit and without filter circuit respectively.

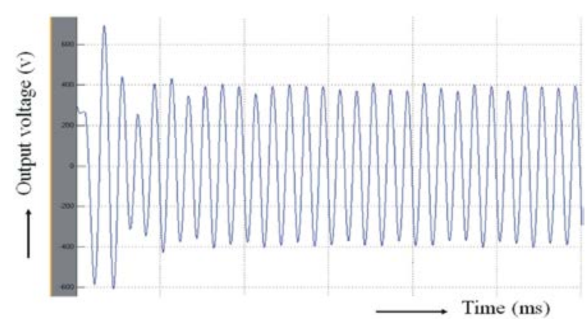


Fig. 5: Output voltage of proposed model with filter circuit

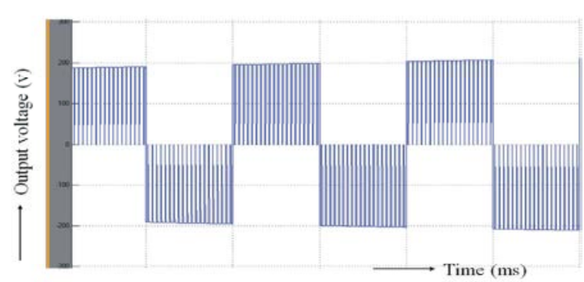


Fig. 6: Output voltage of proposed model without filter circuit

The graphs were derived from three different operating modes, i.e. the system under the condition where the fuel cell energy source, has failed and only the PV source (Cuk converter mode) is supplying power to the load. The second one is the system where only the fuel cell power to the load (SEPIC converter mode).

Finally, the simultaneous operation (Cuk-SEPIC coalition mode) of the two sources where M2 has a longer conduction cycle.

**Experimental Results:**

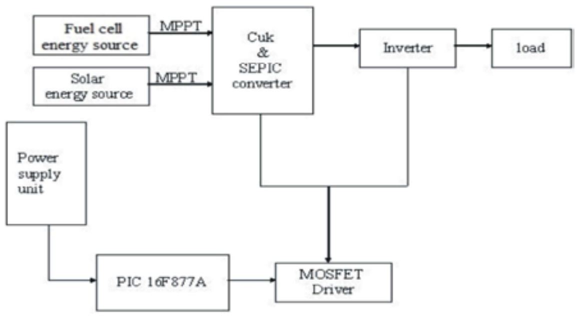


Fig. 7: Block diagram of the hardware module

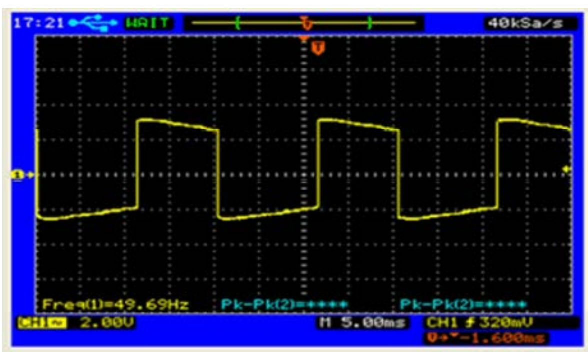


Fig. 8: Output of Fuel Cell model

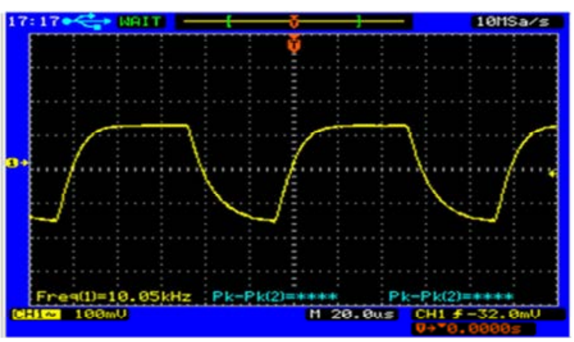


Fig. 9: Output of Solar model

Cuk&SEPIC converter are designed by using capacitor and inductor. For integrating the converter common capacitor bus is used. When the solar source is alone available then the converter acts as a SEPIC converter and when the wind source is alone available then the converter acts as cuk converter.

When both sources are available then the maximum power is tracked by using MPPT algorithm which depends upon the duty cycle of the converters. If the power from solar is maximum then the integrated converter acts as SEPIC converter or if the power from wind is higher than the integrated converter acts as cuk converter.

Finally whatever the input sources the integrated converter act based on that and produces constant boosted output.

Figure 8 and Figure 9 shows the output of fuel cell model and solar model respectively.

## CONCLUSION

This paper is mainly designed for stand-alone fuel cell and solar PV based hybrid energy system for residential application, the proposed converter structure ensures proper operation and also power transfer from solar PV system and fuel cell energy system to a domestic load. The same concept can also be extended to hybrid electric vehicles with help of a multiport DC-DC converter [13] like as the proposed design. The cogency of the experimental waveforms with the simulated results proves the validity of the proposed system as a best alternative for residential applications.

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