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Pv Module Integrated Hybrid Converter IN Stand-ALONE Applications

Ashna Jose[1], Sijo George[2]
[1](PG Scholar, Adi Shankara Institute of Engineering and Technology, Kalady, India)
[2](Asst. Professor, Adi Shankara Institute of Engineering and Technology, Kalady, India)

Abstract: *Renewable energies are derived from natural processes that are replenished constantly and have various forms. Electricity and heat produced from solar, wind, ocean, hydropower, biomass, and geothermal resources are derived from renewable resources. The common inherent drawbacks of renewable energy are unpredictable and intermittent in nature. Hybrid system utilizes two or more energy sources, usually solar with another source power. This paper presents a new system configuration of the front-end converter stage for a hybrid photovoltaic and fuel cell system with maximum power point tracking (MPPT) technique. This configuration allows the two sources to supply the load separately or simultaneously depending on availability. The converter is a combination of CUK and SEPIC converter. The inherent nature of CUK-SEPIC fused converter consists of input inductor to filter out high frequency harmonics, thus additional filter is not required and energy transfer depends on capacitor.*

Keywords: *Hybrid system, CUK-SEPIC converter, photovoltaic system, fuel cell, Maximum power point tracking (MPPT).*

I. Introduction

Renewable Energy Sources are those energy sources which are not destroyed when their energy is harnessed. Human use of renewable energy requires technologies that harness natural phenomena, such as sunlight, wind, waves, water flow, and biological processes such as anaerobic digestion, biological hydrogen production, and geothermal heat. Amongst the above-mentioned sources of energy, there has been a lot of development in the technology for harnessing energy from Solar. Solar is non-deflectable, site dependent, non-polluting, and potential sources of alternative energy options. Many countries are pursuing the option of solar energy conversion systems; in an effort to minimize their dependence on fossil-based nonrenewable fuels [1-3].

Thus intermittent natures of the solar energy make it unreliable source of energy. Hybrid systems are the right solution for a reliable energy production. Therefore, fusing a reliable source with the PV can increase the reliability of the stand-alone system. Here, a comparatively new energy solution is suggested for rural areas and the proposed model will be the alternative to diesel generators and batteries. This paper mainly includes something new, i.e. fuel cell is included in the stand alone power system. Stand-alone power system is an off grid power system that usually operates with renewable energy sources. It is mostly used for remote areas. Hence, hybrid PV with fuel cell energy system can swell up system efficiency and reliability significantly. Because when one source is unavailable or insufficient in meeting the load demands, the other energy source can compensate the load demand. Several alternatives architectures for hybrid PV- fuel cell configuration exit, such as DC/DC boost, DC/DC buck and DC/DC buck-boost converter [1-5]. These configurations inject high-frequency current harmonics [HFCH] into the hybrid system. But boost, buck, and buck-boost converters do not have the capability to eliminate HFCH. So the system requires passive input filters to reduce HFCH that makes the system more bulky and expensive. In this paper, solar-fuel cell energy is integrated together using fusion of CUK-SEPIC converters, so that if one of the sources is unavailable, then the other source can compensate for it and these converters converting unregulated voltage of solar to a fixed high level regulated voltage [1]. Hence, these converters topology are recommended instead of other configurations in order to eliminate the HFCH [7]. They can also support individual and simultaneous operations. Solar energy is the input to the CUK converter and fuel cell energy 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.

II. Proposed Hybrid Converter

A system diagram of the proposed hybrid energy system is shown in Figure 1, where one of the inputs is connected to the output of the PV array and the other input connected to the output of a fuel cell. The fusion 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. When only the wind source is available, 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 Cuk converter. In both cases, both converters have step-up/down capability, which provide more design flexibility in the system if duty ratio control is utilized to perform MPPT control.

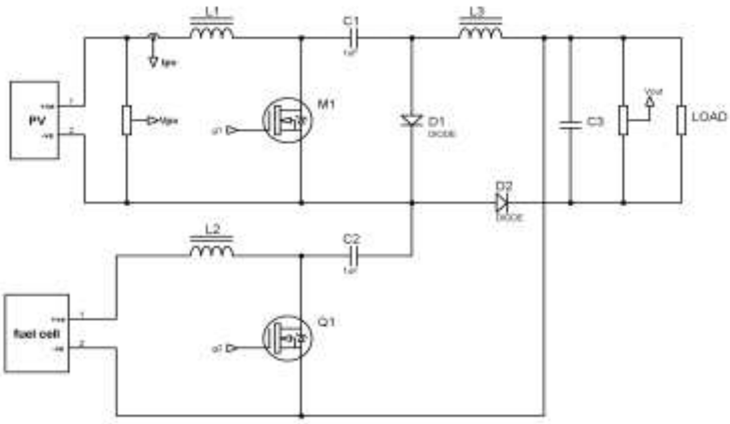


Fig. 1. Proposed Cuk-Sepic fused converter for Hybrid PV/fuel cell system

Figure 2 illustrates the various switching states of the proposed converter. If the turn on duration of M1 is longer than M2, then the switching modes will be mode I, II, IV. Similarly, the switching states will be mode I, III, IV if the switch conduction periods are vice versa.

Mode I (M1-ON, M2-OFF)

In this mode, both the switches M1 and M2 are turn ON. The capacitors C1 and C2 connected across diode D1 and D2 respectively then diodes D1 and D2 experience reverse biased. The equivalent circuit is as shown below

Mode II (M1-ON, M2-OFF)

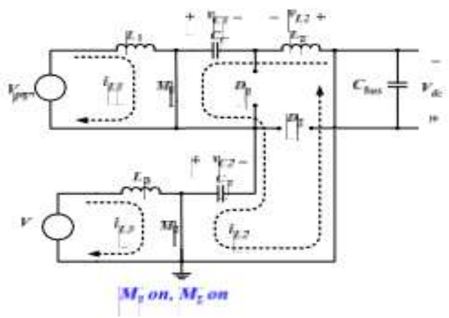
In this mode, the switch M1 turns ON and switch M2 turns OFF. The diode D1 experience reverse biased. The inductor current in L3 forces diode D2 to conduct. The equivalent circuit is as shown in below figure.

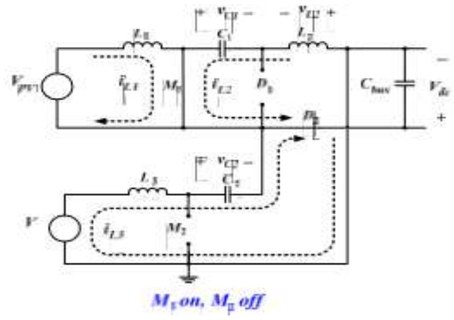
Mode III (M1-OFF, M2-ON)

In this mode, the switch M1 is turn OFF and switch M2 is turn ON. The current in the inductor L1 forces diode D1 to turn ON and diode D2 experience reverse biased. The equivalent circuit is as shown below.

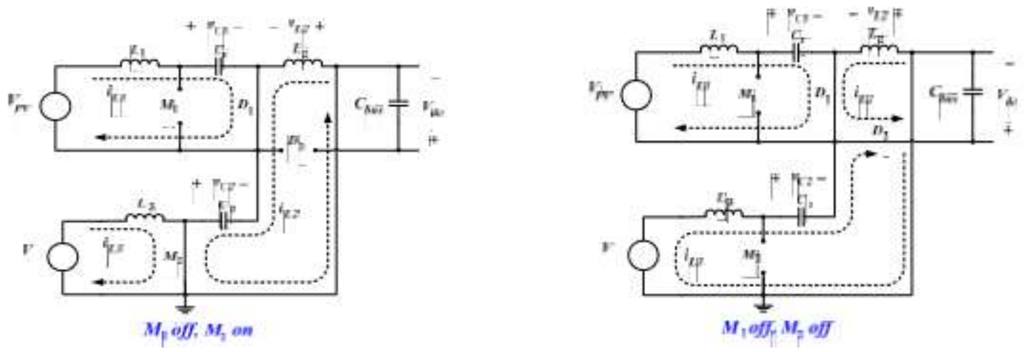
Mode IV (M1-OFF, M2-OFF)

In this mode, the switches M1 and M2 both are turn OFF. The inductor current L1 and L3 forces diode D1 and D3 to conduct respectively. The equivalent circuit is as shown below





(a) (b)



(c) (d)

Fig. 2. Switching modes within a switching cycless

III. MPPT Control Of Proposed Circuit

A common inherent drawback of wind PV systems is the intermittent nature of their energy sources. 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, etc. These drawbacks tend to make these renewable systems inefficient. However, by incorporating maximum power point tracking (MPPT) algorithms, the systems' power transfer efficiency can be improved significantly [6]. The I-V and P-V characteristics of solar cells are affected by conditions of radiation and temperature. The voltage and current should be controlled to track the maximum power of PV systems. MPPT techniques are used to extract the maximum available power from solar cells. Systems composed of various PV modules located at different positions should have individual power conditioning systems to ensure the MPPT for each module. In this paper perturb and observe (P&O) method is used for maximum power point tracking.[8] The voltage from PV array is perturbed in a given direction and if the power drawn from PV array increases, the operating point closer to maximum power pint of P-V curve. If the voltage is perturbed and results in decrease in the power then the point of operation is away from maximum power point. The flow chart is as shown in Fig. 3.

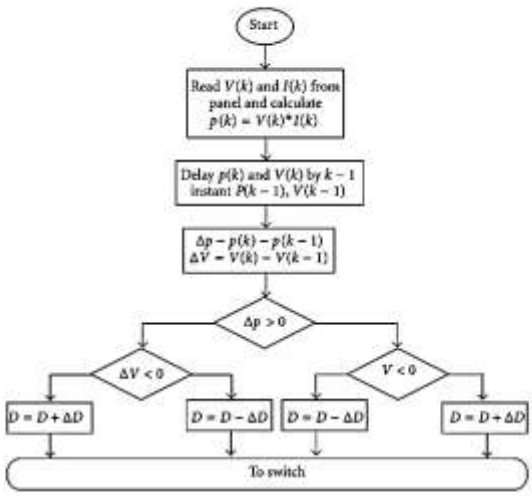


Fig. 3. Flow chart of P&O algorithm

IV. Simulation Results

The hybrid solar and fuel cell energy systems using CUK-SEPIC fused converter is studied and simulated. The simulation tool used is MATLAB. For the variations of temperature and radiation of sun falling on earth the I-V and P-V characteristics gets affected and to overcome the drawback the MPPT technique called perturb and observe method is employed for PV panel. Simulation diagram of Hybrid Cuk-Sepic converter is shown in Fig. 4. Here, PID controller is included for the fuel cell system or sepic converter side to get a constant output voltage of 250v. Input and output voltage waveforms of this hybrid converter is shown in Fig. 5 and Fig. 6 respectively.

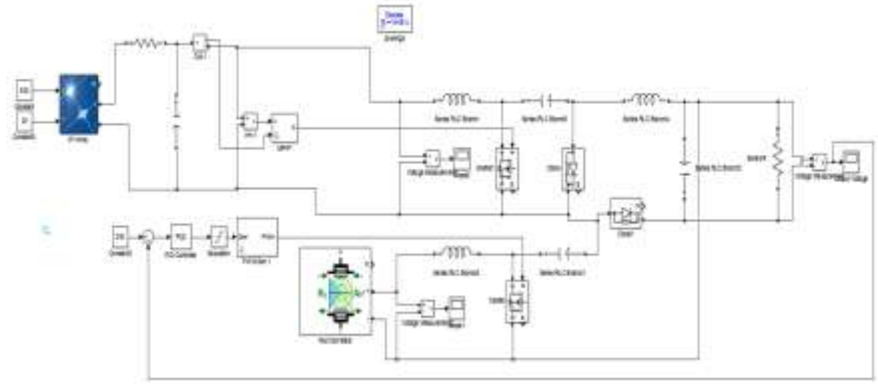
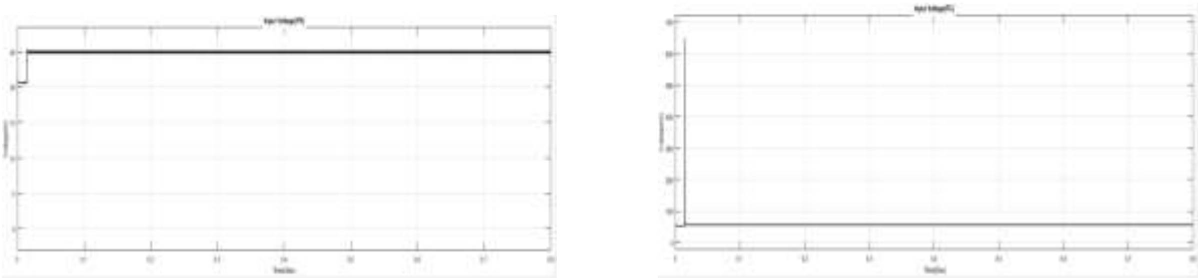


Fig. 4. Simulink diagram of Hybrid Converter



(a) (b)

Fig. 5. (a). PV array voltage input to the converter (b). Fuel cell input voltage to the converter

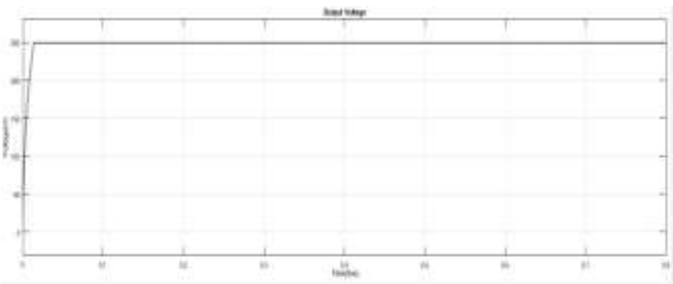


Fig. 6. Output voltage waveform of Hybrid converter

V. Conclusion

Hybridizing solar and fuel cell energy sources provide a realistic form of power generation. Here, a hybrid energy system with a fused converter topology is proposed which makes use of Cuk and SEPIC converters in the design. This converter design overcomes the drawbacks of the conventional multiple boost converters. This topology allows the two sources to supply the load separately or simultaneously depending on the availability of the energy sources. MPPT control is done for PV so that maximum power is tracked and system work more reliably and efficiently. This system has lower operating cost and finds applications in remote area power generation, constant speed and variable speed energy conversion systems and rural electrification. MATLAB/ SIMULINK software is used to model the MPPT controller and proposed hybrid system.

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