SOLAR PV PMSG WIND ENERGY CONVERSION SYSTEM AND BATTERY BASED STANDALONE DC MICRO - GRID SYSTEM

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Abstract

Electricity derived from renewable energy sources are unpredictable and intermittent in nature. Continuous power supply is a challenging task, obtained by maximum utilization of two or more resources resulting in hybrid system. This work proposes a fused converter topology for a hybrid solar/wind system extracting maximum power. The hybrid configuration permits the sources to feed the load individually or simultaneously based on its availability. The proposed converter is the integration of Cuk and SEPIC converter. The characteristic feature of fused Cuk-SEPIC converter is that it removes the high frequency harmonics. Simulation is done using MATLAB/Simulink and an AC output of 300V, 10A is obtained. Hardware implementation is done to validate the performance of the proposed Cuk-SEPIC converter.

Keywords: DC/DC Converter, Fused Cuk-SEPIC Converter, Renewable Energy, Hybrid System

1. INTRODUCTION

Electricity is very much essential for our day to day activities. Nowadays, due to scarcity of fossil fuels, and discharge of greenhouse gases, green energy such as the solar, wind, biomass, geothermal, etc., comes in to play. Researches also has been focused on harvesting green energy. Green energy reduces the emission of greenhouse gases, global warming and is pollution free [1-3]. Among various green energies, solar and wind energy have experienced a prompt growth in recent years. They have unpredictable random behaviors, but complementary profile. Hence there comes the necessity for a hybrid system for the extreme utilization of sources [4-6]. Hybrid system is more beneficial and reliable than isolated system of power generation. Hybrid system is cost effective for rural electrification [7]. When there is failure in one system, the other source generates power and satisfy the demand. In the proposed work, a solar/wind hybrid power generation system model is simulated for household application.

Solar and wind system along with fuel cell is proposed for residential applications [8]. Solar and fuel cell are integrated for distributed generation applications [9]. Power converters are essential for power management between sources and load. The operation of various DC/DC converters like SEPIC, Luo, fused SEPIC and fused Luo are compared for a hybrid system [10]. A boost converter is used in hybrid system for continuous power supply [11].

Multi input fused converters reduces the number of components, dimension and rate of the converter. It also reduces the complexity of the system and supplies load either individually or together depending up on the availability of resources [12]. Multi input converter topology is proposed for diversification of energy in a hybrid system [13-15]. The performance of fused Luo converter is analysed for household applications with reduced ripples [16]. Modified Luo converter topologies have been implemented to improve the voltage gain [17-18]. Cuk-SEPIC converter is used for producing continuous power for a hybrid system [19-20].

The main objective of the proposed work is to obtain continuous power, satisfying the load demand effectively. An integrated positive output Cuk-SEPIC converter topology fed by solar and wind energy system is proposed to supply power continuously to the load based on the availability of the resource. It also filter out the high frequency harmonics and develops the efficiency of the system.

The paper is organized as follows: Section 2 introduces the block diagram of the solar/wind hybrid system. Section 3 explains the various operating modes of the proposed Cuk-SEPIC converter. In section 4 simulation analysis is done and results are discussed. Hardware implementation is done in section 5. Conclusions are made in section 6.

2. BLOCK DIAGRAM OF SOLAR/WIND HYBRID SYSTEM

The intensity of the sun does not exist throughout the day, likewise the wind speed will not be heavy for the whole day. Hence, for uninterrupted power supply a distinct source cannot be an enhanced option. The hybrid combination harvests power from both sun and wind are stores the excess energy in the battery. So that the battery delivers the load even in the absence of sun light or wind. Hybrid system is employed for low cost and is more reliable. The block diagram of solar/wind hybrid system is presented in figure 1. Solar energy and wind energy are the inputs to the DC/DC converter. The proposed converter is the fusion of Cuk and SEPIC converters. It eliminates the need for separate passive filter. The output of the converter is directed to an inverter, which converts DC power to AC power, thereby it supplies AC loads.

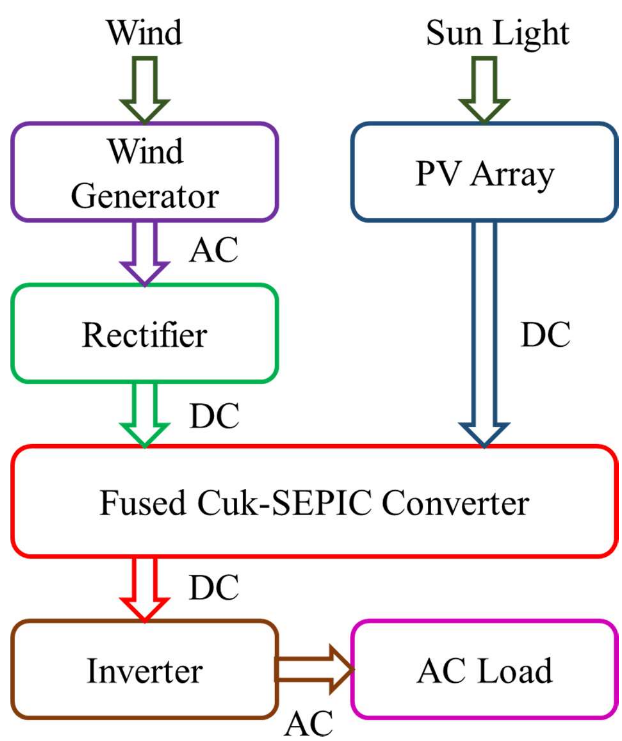

Fig. 1 Block Diagram of Solar/Wind Hybrid System

3. OPERATING MODES OF CUK-SEPIC CONVERTER

DC/DC converters act as a switched regulators used to convert an irregular DC input to a controlled DC output. Cuk and SEPIC converters are types of DC/DC converter that helps to increase or decrease the input voltage. Both converters can perform boost and buck operations. Cuk converter has negative polarity, whereas SEPIC converter has positive polarity in the output.

Fused converters shrinks the number of components used in the circuit, which in turn lessens the cost of the converter. Moreover, it filters high frequency harmonics too. In the proposed work, Cuk and SEPIC converters are fused together to form a fused Cuk-SEPIC converter. The diodes of each converters are rearranged and the output inductor and capacitor are shared between the two converters. The equivalent circuit of the fused Cuk-SEPIC converter is exposed in figure 2. Based on the availability of resource, the proposed converter supplies the load.

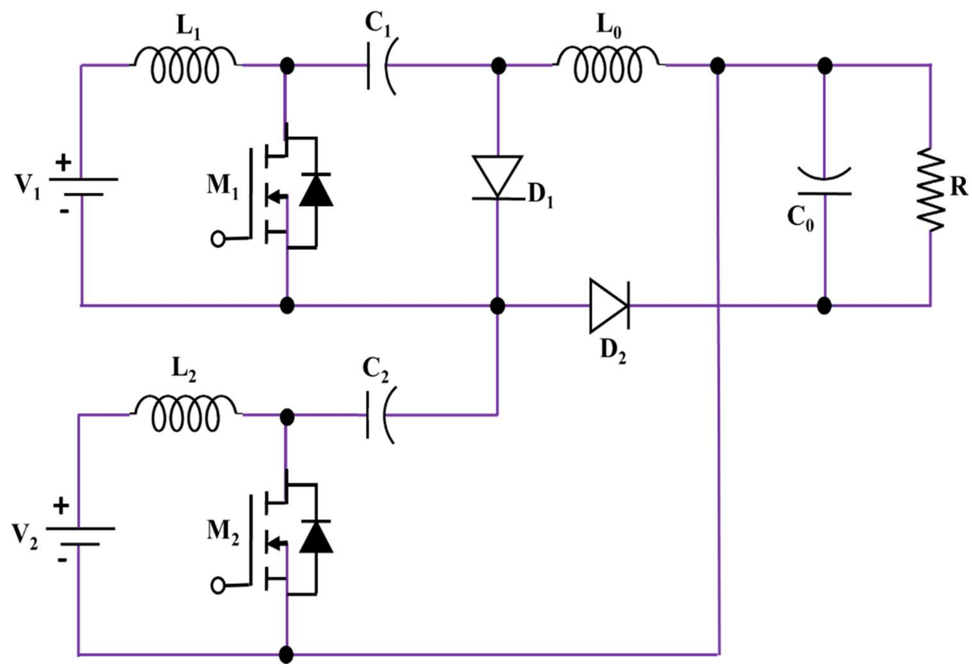

Fig. 2 Fused Cuk-SEPIC Converter

Let V_1 and V_2 be the DC output voltages from the solar and wind system respectively. MOSFET M_1 and M_2 act as switches to connect solar and wind systems. The various operating modes of fused Cuk-SEPIC converter are briefed below.

3.1 Mode 1: Both sources are active

In this mode, both solar and wind systems are active for the generation of power. In this mode, switches M_1 and M_2 are ON and diodes D_1 and D_2 are in reverse biased condition. The supply voltages V_1 and V_2 charges the inductors L_1 and L_2 respectively. The capacitors C_1 and C_2 starts discharging to charge inductor L_0 which in turn charges the capacitor C_0. The equivalent circuit when both sources are active is shown in figure 3.

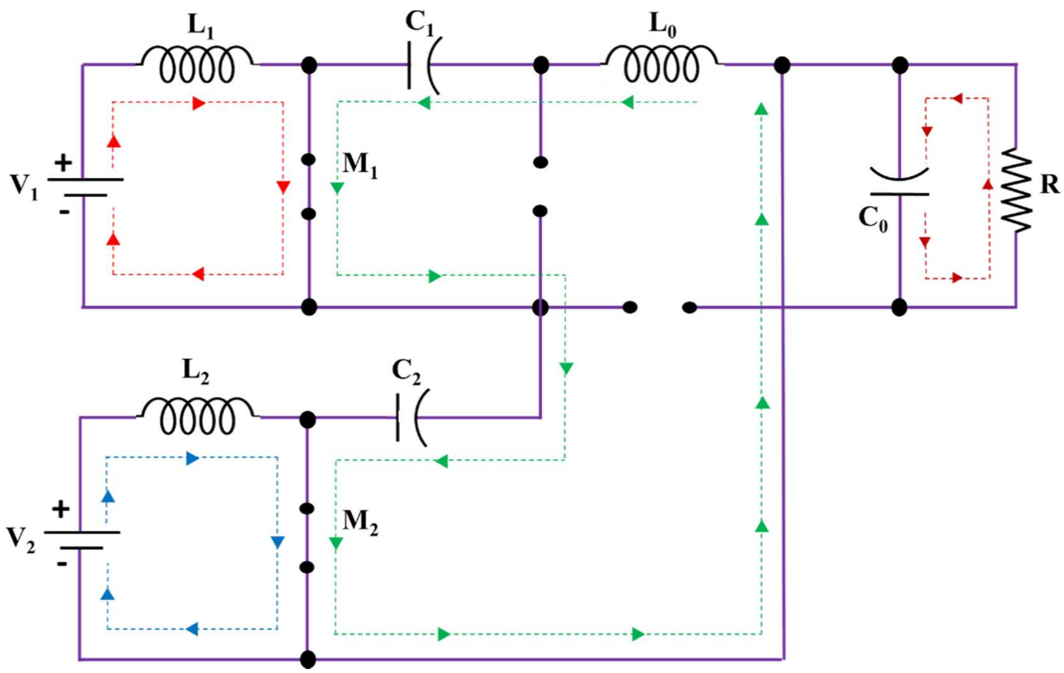

Fig. 3 Mode I Equivalent Circuit

3.2 Mode 2: Only solar source is active

In this mode, only solar system is active for power generation. Here, switch M_1 is ON and switch M_2 is OFF. Diode D_2 is in forward biased and D_1 in reverse biased conditions. The Inductor L_1 is charged by the solar voltage V_1. The capacitor C_2 discharges through the diode D_2 and charges the inductor L_2. Meanwhile, capacitor C_1 starts discharging and charges the inductor L_0. Figure 4 shows the equivalent circuit during the presence of solar source alone.

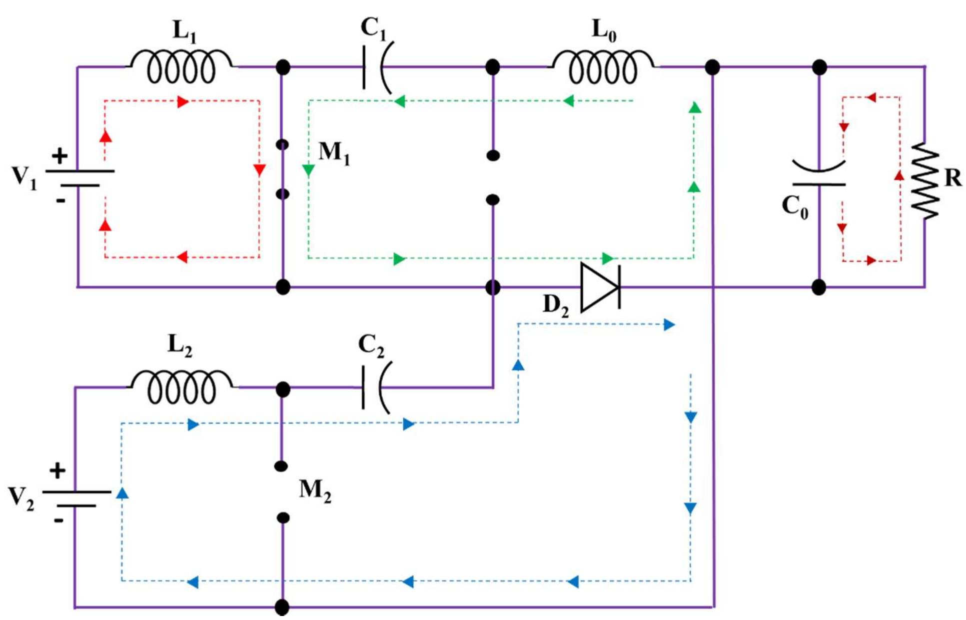

Fig. 4 Mode II Equivalent Circuit

3.3 Mode 3: Only wind source is active

In this mode, only wind system is active for power generation. In this mode, switch M_2 is ON while switch M_1 is OFF. Diode D_1 is in forward biased and D_2 in reverse biased conditions. Here the inductor L_2 is charged by the wind voltage V_2. The capacitor C_1 discharges through the diode D_1, thereby charges the inductor L_1. Meanwhile, the capacitor C_2 discharges and charges the inductor L_0. Figure 5 shows the equivalent circuit during the presence of wind source alone.

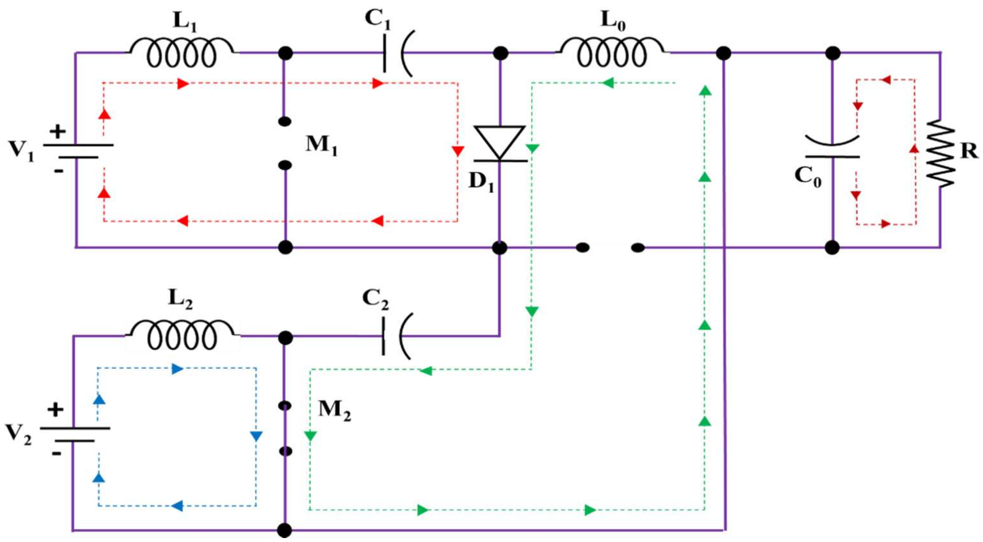

Fig. 5 Mode III Equivalent Circuit

3.4 Mode 4: Both sources are inactive

In fourth mode, both the sources are not connected to the system for power generation. Here, switches M_1 and M_2 are OFF and diodes D_1 and D_2 are in forward biased condition. The inductor L_1 discharges through the diode D_1 due to which the capacitor C_1 is charged. Inductor L_2 discharges through the diode D_2, thereby charging the capacitor C_2. At the same time, inductor L_0 discharges to charge the capacitor C_0, thereby feeds the load R. The equivalent circuit during the absence of both solar and wind sources is shown in figure 6.

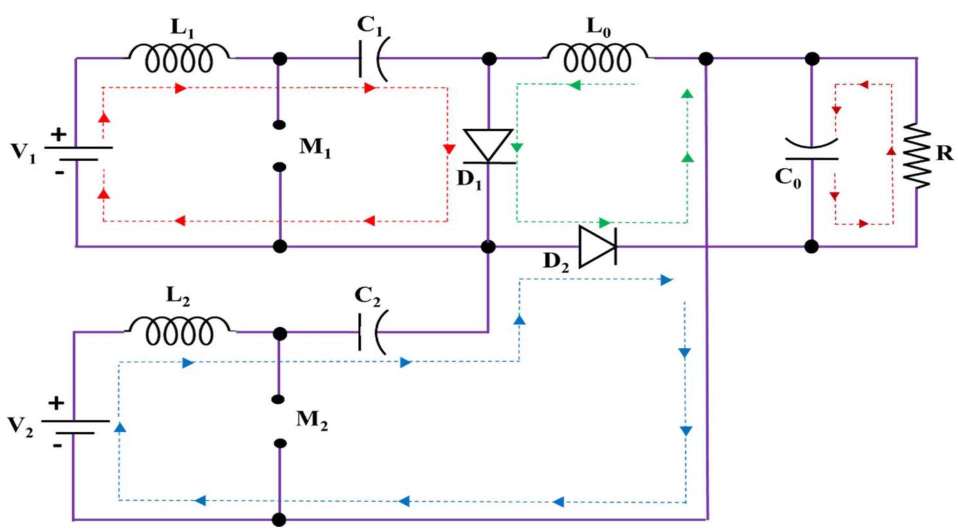

Fig. 6 Mode IV Equivalent Circuit

4. SIMULATION ANALYSIS

The simulation model of fused Cuk-SEPIC converter based solar/wind hybrid system is presented in figure 7. The solar and wind sources are connected to the fused Cuk-SEPIC converter. A battery is connected at the output of the converter to store excess energy. The converter provides continuous power to the load either with the help of solar source or wind source or battery based on the availability. The values of components used in the fused Cuk-SEPIC converter is tabulated in table 1. The output from the converter is DC and for AC applications, an inverter circuit should be connected to the converter. Thus, DC output is inverted into AC power to supply AC loads.

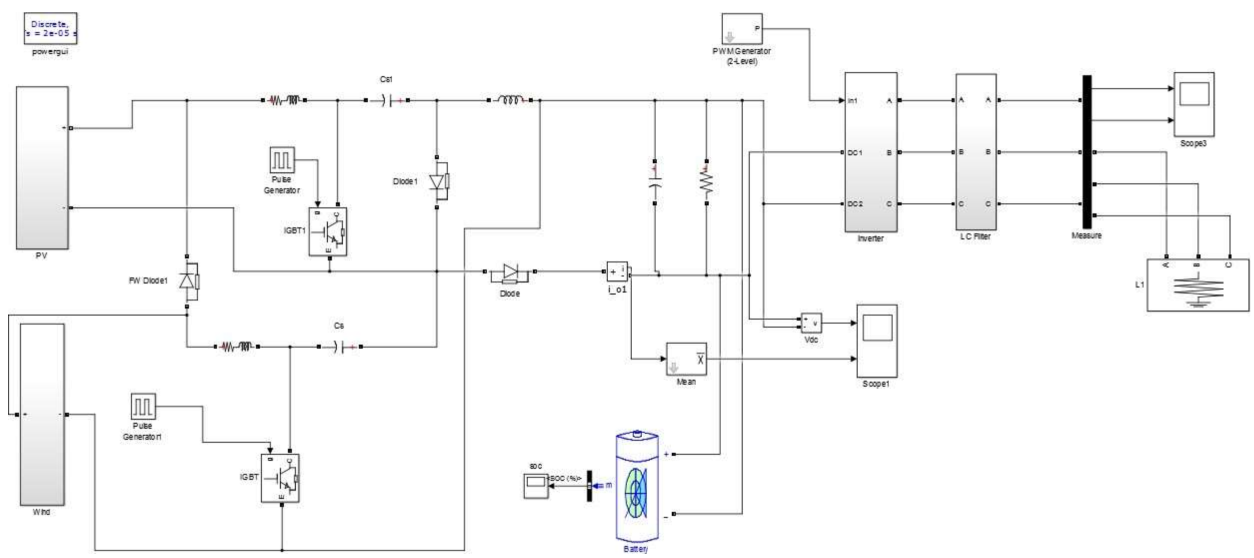

Fig. 7 Simulation Model of Fused Cuk-SEPIC Converter based Solar/Wind Hybrid System

Table 1: Components of Fused Cuk-SEPIC Converter

S. No.	Components	Values
1	Inductor L_1	700µH
2	Inductor L_2	700µH
3	Inductor L_0	700µH
4	Capacitor C_1	3.3µH
5	Capacitor C_2	3.3µH
6	Capacitor C_0	1000µH
7	Resistor R	47Ω
8	Frequency	15KHz

The solar module produces an output voltage of 630V and current of 1.8A as shown in figure 8. Likewise the wind module produces an output voltage of 400V and current of 11A as figure 9. The output from solar and wind modules are fed to the fused Cuk-SEPIC converter. The proposed fused Cuk-SEPIC converter produces an output of 530V and 2.4A as figure 10. The inverter converts 530V, 2.4A DC in to 300V, 10A AC. The inverter output is shown in figure 11. The proposed system can be used for household applications. The output obtained from solar, wind, converter and inverter modules are summarized in table 2.

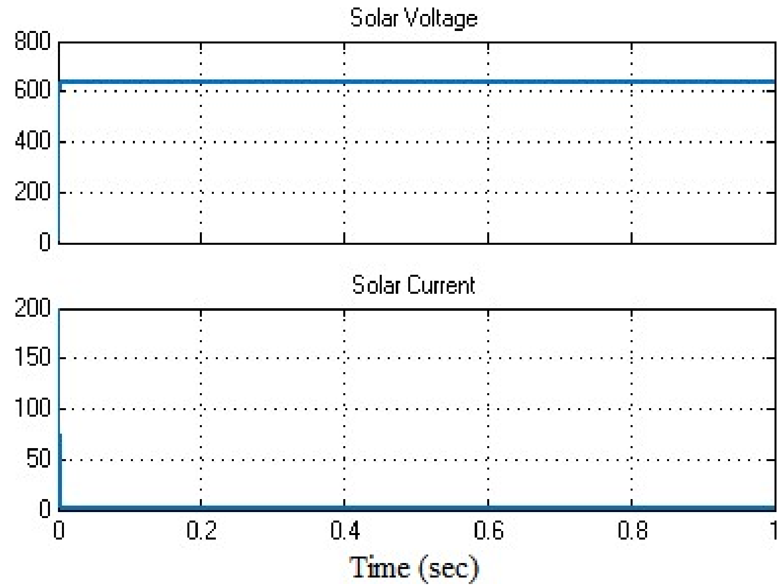

Fig. 8 Solar Voltage and Current

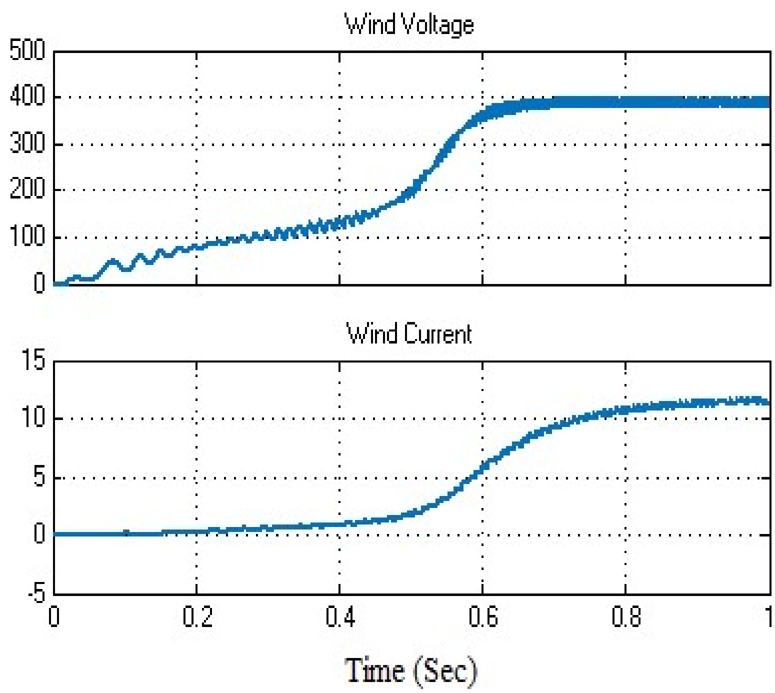

Fig. 9 Wind Voltage and Current

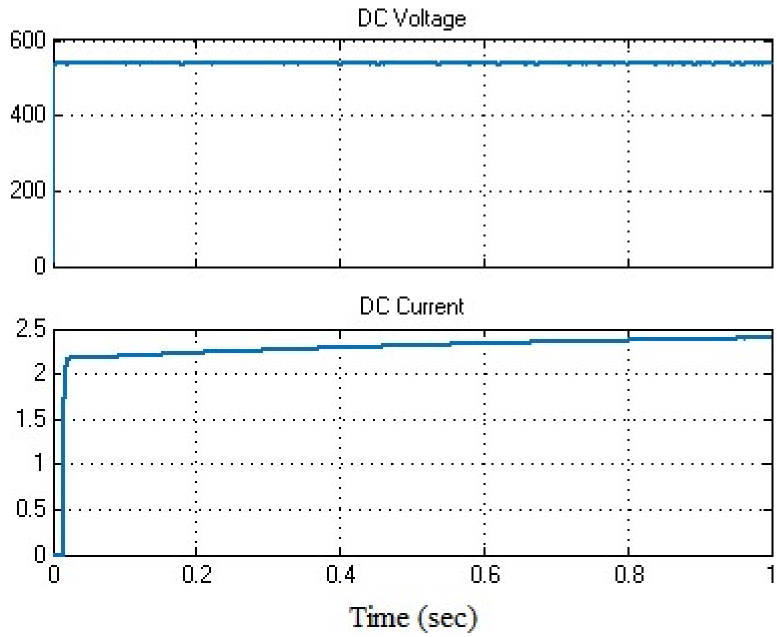

Fig. 10 Fused Cuk-SEPIC Converter Output

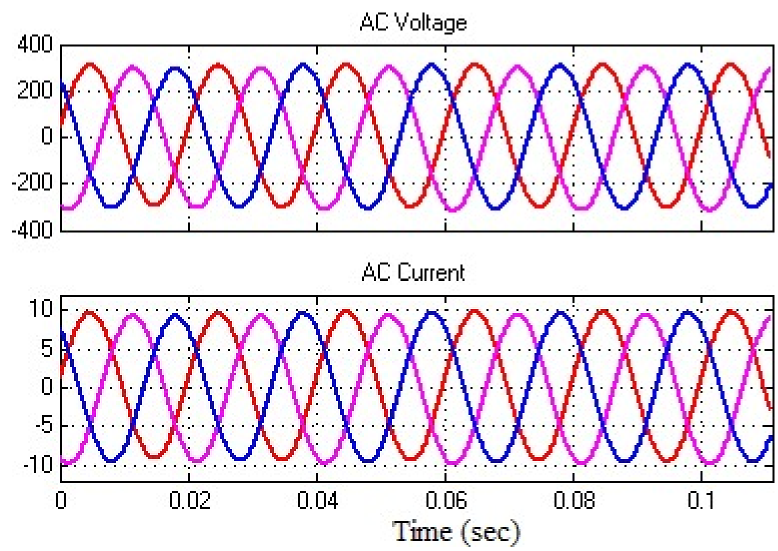

Fig. 11 Inverter Output

Table 2: Output from Solar, Wind, Converter and Inverter Modules

S.No.	Parameters	Values
1	Solar Voltage	630V
2	Solar Current	1.8A
3	Wind Voltage	400V
4	Wind Current	11A

5	Converter Voltage	530V
6	Converter Current	2.4A
7	Inverter Voltage	300V
8	Inverter Current	10A

5. HARDWARE IMPLEMENTATION

The hardware prototype of the fused Cuk-SEPIC converter based solar/wind hybrid system is displayed in figure 12. Here a solar panel of 12V, 5W, a DC generator of 6V, 5W and a battery of 12V, 1.3Ah is connected to the proposed fused Cuk-SEPIC converter. For hardware implementation, DC generator is used instead of wind turbine. The inductor and capacitor values used in fused Cuk-SEPIC converter is taken as 20mH and 470μF respectively. The requirements of various components used for implementing the hardware prototype is specified in table 3. A transformer of 12V is used to boost the output voltage and a lamp is considered as the load. The lamp keeps on glowing continuously receiving power either from solar panel or DC generator or battery. Thus continuous power is generated by the proposed Cuk-SEPIC fused converter.

Fig. 12 Hardware Prototype

Table 3: Specification of Components

S.NO.	Components	Specification
1	Solar Panel	12V, 5W
2	DC Generator	6V, 5W
3	Battery	12V, 1.3Ah
4	MOSFET	600V, 1.7Ω, N-channel
5	Diode	IN4007
6	Inductor	20mH
7	Capacitor	470µF
8	Resistor	100Ω
9	Driver Circuit	FAN7392N
10	Transformer	12V

6. CONCLUSION

A Cuk-SEPIC fused converter topology has been proposed for solar/wind hybrid energy system. Two separate DC/DC converters are integrated together, so that the count of components, size and complexity of the system is reduced. The proposed converter allows both the solar and wind sources to feed the load separately or combined together based on the accessibility. It removes the high frequency harmonics without any additional filters and enhances the effectiveness of the system. The battery supplies the load in the absence of solar and wind sources. Thus, uninterrupted power is attained due to the proposed fused Cuk-SEPIC converter topology. An AC output of 300V, 10A is obtained based on the simulation analysis using MATLAB/Simulink. Hardware implementation has been done to verify the performance of the proposed Cuk-SEPIC converter. The proposed system finds its applications in domestic purposes like street lighting, traffic signals, pump irrigation systems and various communication and monitoring systems. The proposed hybrid system is applied for remote area power generation and rural electrification.

REFERENCES

[1] N.L. Panwar, S.C. Kaushik and Surendra Kothari, “Role of renewable energy sources in environmental protection: A review”, Renewable and Sustainable Energy Reviews, vol.15, pp. 1513–1524, 2011.

[2] Athanasios Angelis-Dimakis, Markus Biberacher, et al., “Methods and tools to evaluate the availability of renewable energy sources”, Renewable and Sustainable Energy Reviews, vol. 15, pp. 1182–1200, 2011.

[3] Yakup Çelikbilek and Fatih Tuysuz, “An integrated grey based multi-criteria decision making approach for the evaluation of renewable energy sources”, Energy, vol. 115, pp. 1246-1258, 2016.

[4] K. Shivarama Krishna and K. Sathish Kumar, “A review on hybrid renewable energy systems”, Renewable and Sustainable Energy Reviews, vol. 52, pp. 907–916, 2015.

[5] Vikas Khare, Savita Nema and Prashant Baredar, “Solar–wind hybrid renewable energy system: A

review", Renewable and Sustainable Energy Reviews, vol.58, pp. 23–33, 2016.

[6] Vikas Khare, Savita Nema and Prashant Baredar, "Status of solar wind renewable energy in India", Renewable and Sustainable Energy Reviews, vol. 27, pp. 1-10, July 2013.

[7] W. Margaret Amutha and V. Rajini, "Cost benefit and technical analysis of rural electrification alternatives in southern India using HOMER", Renewable and Sustainable Energy Reviews, vol. 62, pp. 236–246, May 2016.

[8] Nabil A. Ahmed, Masafumi Miyatake and A.K. Al-Othman, "Power fluctuations suppression of stand-alone hybrid generation combining solar photovoltaic/wind turbine and fuel cell systems", Energy Conversion and Management, vol. 49, no. 10, pp. 2711-2719, Oct 2008.

[9] Sachin Jain and Vivek Agarwal, "An Integrated Hybrid Power Supply for Distributed Generation Applications Fed by Nonconventional Energy Sources", IEEE Transactions on Energy Conversion, vol. 23, no. 2, pp. 622-631, June 2008.

[10] S.M. Shyni and R. Ramadevi, "Performance Comparison of SEPIC, Luo, Fused SEPIC and Fused Luo Converter Topologies for Hybrid Green Energy System", Journal of Green Engineering, vol. 10, no. 9, Sep 2020.

[11] Ramon G. Garcia, Ernesto M. Vergara, et al., "Design and Implementation of a DC-DC Boost Converter for Continuous Hybrid Power System", International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management, Jan 2018.

[12] Zubair Rehman, Ibrahim Al-Bahadly and Subhas Mukhopadhyay, "Multiinput DC–DC converters in renewable energy applications – An overview", Renewable and Sustainable Energy Reviews, vol. 41, pp. 521–539, 2015.

[13] Lalit Kumar, Shailendra Jain, "Multiple-input DC/DC converter topology for hybrid energy system", IET Power Electronics, vol.6, no.8, pp.1483- 1501, Sep 2013.

[14] Ting-Chia Ou, Whei-Min Lin and Cong-Hui Huang, "A Multi-Input Power Converter for Hybrid Renewable Energy Generation System", Conference on Sustainable Alternative Energy, IEEE, 2010.

[15] Zhijun Qian, Osama Abdel-Rahman and Issa Batarseh, "An Integrated Four-Port DC/DC Converter for Renewable Energy Applications", IEEE Transactions On Power Electronics, vol. 25, no. 7, pp. 1877-1887, 2010.

[16] S. M Shyni and R. Ramadevi, "Design of Fused Luo Converter Based Solar/ Wind Hybrid System for Household Application", Journal of Critical Reviews, vol. 7, no. 14, pp. 1911-1920 2020.

[17] Sivakumar Arumugam and Premalatha Logamani, “Modeling and adaptive control of modified LUO converter”, Microprocessors and Microsystems, vol. 71, pp. 1-13, 2019.

[18] Yefim Berkovich, Boris Axelrod, Rotem Madar and Avraham Twina, “Improved Luo converter modifications with increasing voltage ratio”, IET Power Electronics, vol. 8, no. 2, pp. 202–212, 2015.

[19] Joanne Hui, Alireza Bakhshai and Praveen K. Jain, “A Hybrid Wind-Solar Energy System: A New Rectifier Stage Topology”, IEEE Applied Power Electronics Conference and Exposition, pp. 155-161, 2010.

[20] Kumar. K, Ramesh Babu. N and Prabhu K.R, “Design and Analysis of an Integrated Cuk-SEPIC Converter with MPPT for Standalone Wind/PV Hybrid System”, International Journal of Renewable Energy Research, vol. 7, no. 1, pp. 96-106, 2017.