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# A Cuk-Sepic Fused Converter Based Wind-Solar Hybrid System

**Ayushi Sawarkar[1], Hemant Maind[2], Swapnil Thakre[3], Swati Pande[4], Neha Mehar[5], Manoj Banvaskar[6], K.M. Denge[7]**

Students, Dept of Electrical Engg, K.D.K.C.E, Nagpur, MS, India[1,2,3,4,5,6]

Professor, Dept of Electrical Engg, K.D.K.C.E, Nagpur, MS, India[7]

**Abstract:** Conventional sources are deteriorating the planet; therefore environmental friendly technological solutions are becoming more prominent. This paper presents a new system configuration of the front end rectifier stage for a hybrid wind-photovoltaic energy system. This configuration allows the two sources to supply the load separately or simultaneously together depending on the availability of the energy sources. The proposed design has the Cuk and Sepic converters combined together which eliminate the need of additional input filters to filter out the high frequency harmonics. The fused multiinput rectifier stage also allows Maximum Power Point Tracking (MPPT) to be used to extract maximum power from the wind and sun when it is available. A standard perturb and observe method will be used for PV system and wind energy system. Simulation results were obtained using MATLAB/Simulink.

**Keywords:** Cuk converter, sepic converter, Maximum Power Point Tracking (MPPT), DC-DC converter, wind energy, solar energy.

## I. INTRODUCTION

The ever-increasing demand for conventional energy sources like coal, natural gas and crude oil is driving society towards the research and development of alternate energy sources. Many such energy sources like wind energy and photovoltaic are now well developed, cost effective and are being widely used, while some others like fuel cells are in their advanced developmental stage. These energy sources are preferred for being environmental-friendly.

A.Hybridization of Renewable energy sources

In order to satisfy the load demand, one or more renewable energy sources can be combined together. A wind and solar hybrid system can supply more stable power than a single wind or PV source.

The features of the proposed topology are:

1) The inherent nature of these two converters eliminates the need for separate filters;

2) It can support step up/down operations for each renewable source (can support wide ranges of PV and wind input);

3) MPPT can be realized for each source;

4) Individual and simultaneous operation is supported.

## II. HYBRID SYSTEM WITH MULTI-CONNECTED BOOST CONVERTER

The structure shown here is a fusion of the buck and buck-boost converter. This require passive input filters to remove the high frequency current harmonics injected into wind turbine generators .The harmonic content in the generator current decreases its lifespan and increases the power loss due to heating .

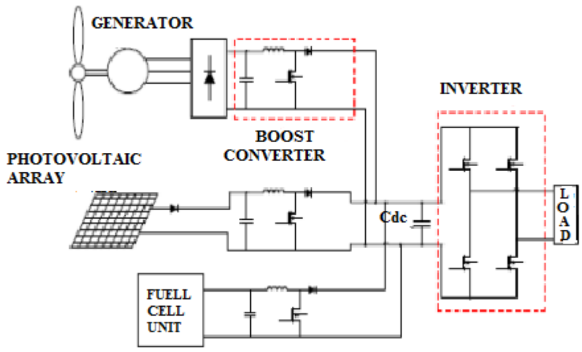


Fig 1: Hybrid system with multi-connected boost converter

## III. PROPOSED SYSTEM

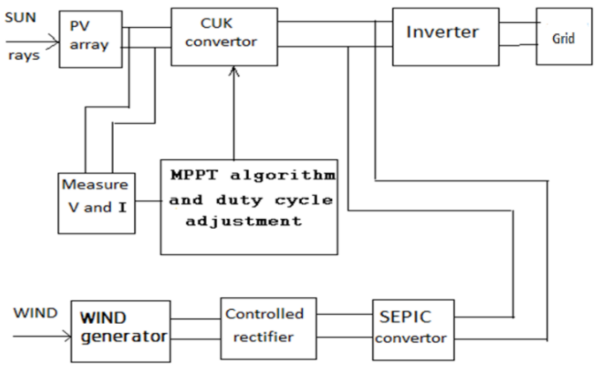


Fig 2: Block diagram of proposed system

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An alternative multi-input rectifier structure is proposed for hybrid wind and solar energy systems as shown in fig 2. The proposed design is a fusion of CUK and SEPIC converters which eliminate the need for separate passive filter and support step up/down operations for renewable energy sources. Here one of the inputs is connected to the output of the PV array and the other input connected to the output of a wind generator.The fusion of the two converters is achieved by reconfiguring the two existing diode from each converter and the shared utilization of the CUK output inductor by the SEPIC converter.

A. Pv cell and its characteristics
A solar cell is comprised of a P-N junction semiconductor that produces currents via the photovoltaic effect. A PV cell is a diode of a large-area forward bias with a photo voltage and the equivalent circuit is shown by Figure [3].The current-voltage characteristic of a solar cell is derived as follows:

$$I = Iph - I_D \qquad (1)$$

Where
$I_{ph}$= photocurrent,
$I_D$=diode current,
$I_0$= saturation current,
A =Ideality factor,
q =Electronic Charge $1.6 x 10^{-9}$,
k =Boltzmann's gas constant ($1.38 x 10^{-23}$),
T =Cell Temperature,
$R_s$=Series Resistance,
$R_{sh}$=Shunt resistance,
I = Cell current,
V = Cell voltage,
$T_{op}$=Cell operating temperature in $^o$ c
$T_{ref}$=Cell temperature at $25^0$ c
$E_g$=Band gap energy of cell, 1.12eV

Typically, the shunt resistance (Rsh) is very large and the series resistance (Rs) is very small. Therefore, it is common to neglect these resistances in order to simplify the solar cell model. The resultant ideal voltage-current characteristic of a photovoltaic cell is given by (2) and illustrated by Figure [4].

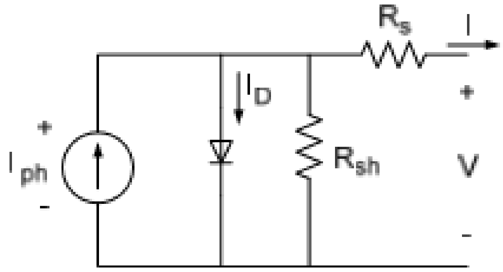

Fig 3: PV cell equivalent circuit

$$I = Iph - Io(\exp\left(\frac{qV}{kT}\right) - 1)1 \qquad (2)$$

The typical output power characteristics of a PV array under various degrees of irradiation is illustrated by Figure [4].

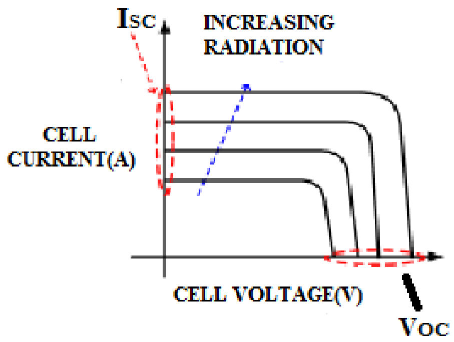

Fig 4: PV cell voltage-current characteristic

B.Wind turbine and its characteristics
To describe a wind turbine's power characteristic, equation (3) describes the mechanical power that is generated by the wind.

$$P_m = 0.5\square\, A C_p(\square, \square) v^3 \qquad (3)$$

Where
ρ = air density,
A = rotor swept area,
Cp (λ, β) = power coefficient function
λ =tip speed ratio
β = pitch angle,
$v_w$=wind speed

The power coefficient (Cp) is a nonlinear function that represents the efficiency of the wind turbine to convert wind energy into mechanical energy. It is dependent on two variables, the tip speed ratio (TSR) and the pitch angle. The TSR, λ, refers to a ratio of the turbine angular speed over the wind speed. The mathematical representation of the TSR is given by (4). The pitch angle, β, refers to the angle in which the turbine blades are aligned with respect to its longitudinal axis.

$$\lambda = (R\, \omega_b)/v_m \qquad (4)$$

Where
R = turbine radius
ωb=angular rotational speed

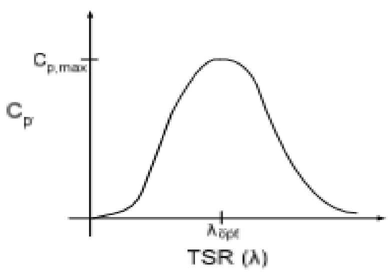

Figure 4: Power Coefficient Curve for a typical wind turbine

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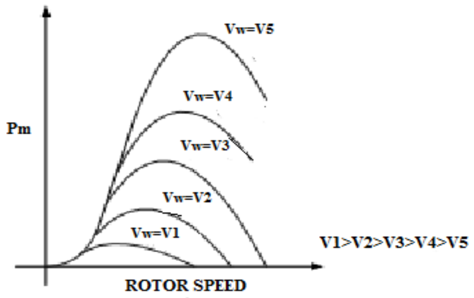


Fig 5: Power Curves for a typical wind turbine

C. 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 has the capability for both step up and step down operation. The output polarity of the converter is negative with respect to the common terminal

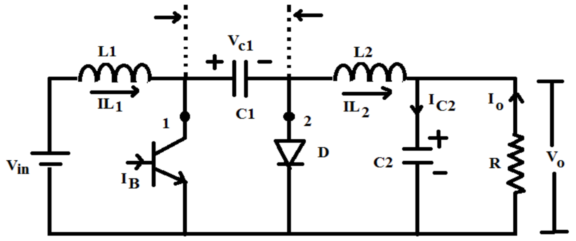


Fig 6.Circuit diagram of the Cuk converter

D: SEPIC Converter

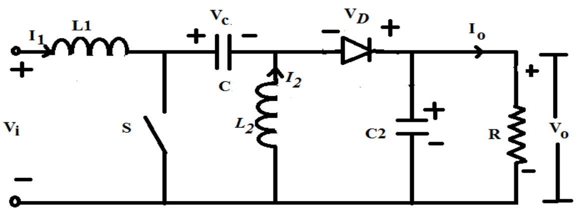


Fig 7.Circuit diagram of the Sepic converter

The SEPIC officially stands for "Single-Ended Primary Inductance 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.

E. Modes of CUK-SEPIC converter

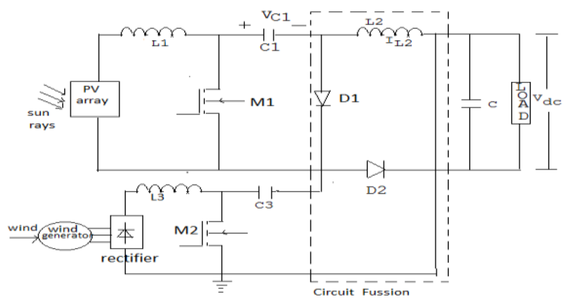


Fig 8: Circuit Diagram of CUK-SEPIC fused converter

The various switching states of the proposed converter are shown in fig 9-12. 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.

1) Mode I (M1-ON, M2-OFF): In this mode both solar energy and wind energy is available, 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:

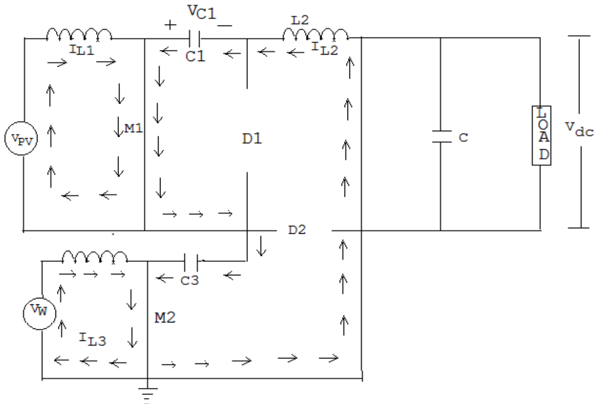


Fig 9: Circuit configuration when both sources are available

2) Mode II (M1-ON, M2-OFF): In this mode only solar energy is available and wind energy is not available. 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.

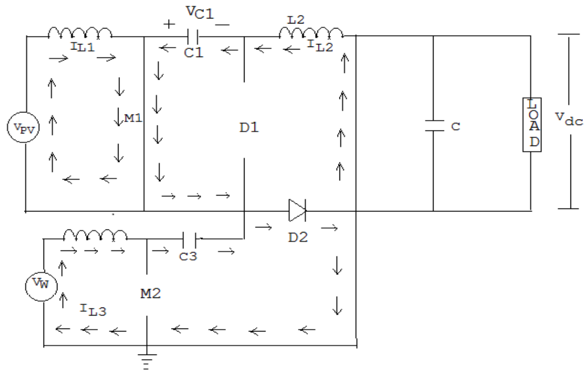


Fig 10: Circuit configuration when only solar energy is available

3) Mode III (M1-OFF, M2-ON): In this mode only wind energy is available and solar energy is not available. 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.

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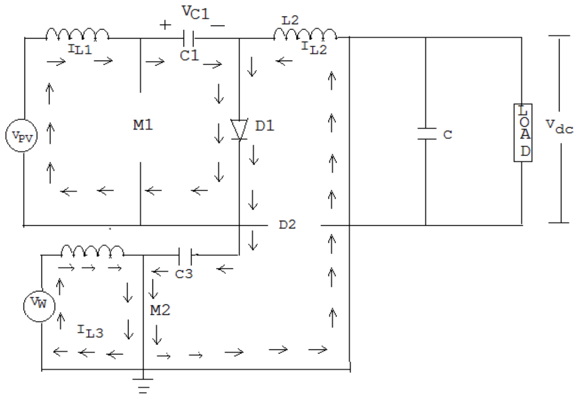


Fig 11: Circuit configuration when only wind energy is available

4) Mode IV (M1-OFF, M2-OFF): In this mode both solar energy and wind energy is unavailable. 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.

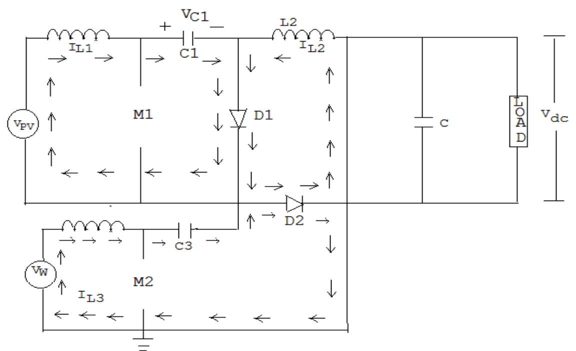


Fig 12: Circuit configuration when both sources are not available

F. MPPT control of proposed circuit

Due to the similarities of the shape of the wind and PV array power curves, a similar maximum power point tracking scheme known as the hill climb search (HCS) strategy is often applied to these energy sources to extract maximum power. The HCS strategy perturbs the operating point of the system and observes the output. If the direction of the perturbation (e.g. an increase or decrease in the output voltage of a PV array) results in a positive change in the output power, then the control algorithm will continue in the direction of the previous perturbation. Conversely, if a negative change in the output power is observed, then the control algorithm will reverse the direction of the pervious perturbation step. In the case that the change in power is close to zero (within a specified range) then the algorithm will invoke no changes to the system operating point since it corresponds to the maximum power point (the peak of the power curves). The MPPT scheme employed in this paper is a version of the HCS strategy. Figure 13 is the flow chart that illustrates the implemented MPPT scheme.

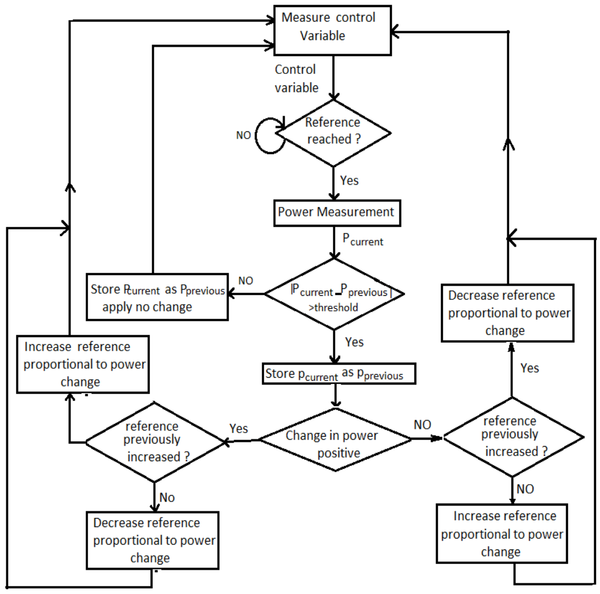


Fig 13: General MPPT Flow Chart for wind and PV

## IV. SIMULATION RESULTS

In this section, simulation results from MATLAB are given to verify that the proposed multi-input rectifier stage can support individual as well as simultaneous operation. The specifications for the design example are given in TABLE I.

TABLE I: SPECIFICATIONS OF DESIGN

| | |
|---|---|
| Output power(W) | 3000 W |
| Output Voltage(V) | 500 V |
| Switching Frequency(kHz) | 20kHz |

A. Simultaneous operation with both wind and PV source (Fusion mode with Cuk and SEPIC)

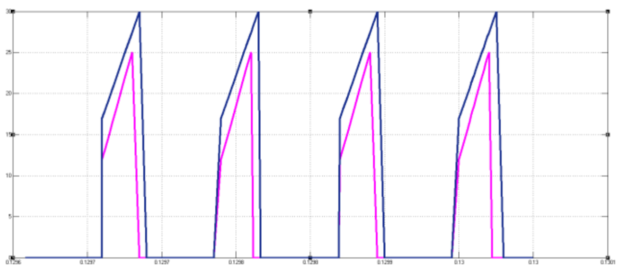

Fig 14.Switch currents (M1 and M2)

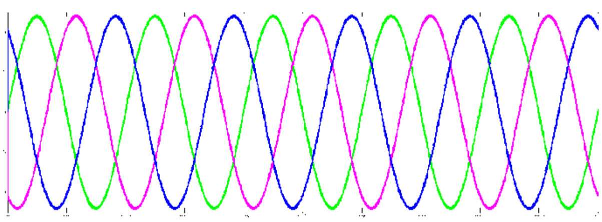

Fig 15. The injected three phase generator current

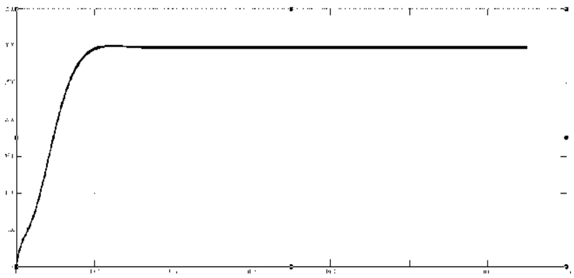

Fig 16. Output power

## V. CONCLUSION

Instead of conventional boost converter, in this paper, the multi input CUK-SEPIC converter has been proposed for wind and solar energy system. The system is advantageous compared to conventional system:

1) Filters for eliminating high frequency harmonics are not required.
2) Both wind and the solar energy can be stepped up and stepped down.
3) The MPPT can be realized for each source.
4) Individual and simultaneous operation is supported.

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