A New Rectifier Stage Topology with SEPIC Converter for Wind Energy System

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ABSTRACT: Coal, oil and natural gas are the three primary sources of energy in India, despite of these 56 percent of households do not have electricity connections and frequent power cuts and shortages force a heavy burden on fast growing industries. This paper shows a new rectifier with SEPIC configuration for Wind energy systems, wind energy does not cause greenhouse gases or any other pollutant. The use of SEPIC converter allows us to meet the load requirement either by stepping up or stepping down the voltage levels and it also filters out the high frequency harmonics from the signal. Harmonics in the system decreases the generator lifespan, efficiency and causes heating problems. The stepped DC voltage is converted to AC and given to the load through an inverter. The system can be used for AC or DC loads.

KEYWORDS: Wind energy, SEPIC converter, Rectifier.

I.INTRODUCTION

Since global warming has become a big concern and fossil fuels are eliminating there is a need for another energy source on which we can depend. Wind power generation is an important solution for mitigation the problems due to its smaller environmental impact and its renewable characteristics (5). The conversion of wind energy into a useful form of energy is known as wind power, like wind turbine is used to produce electrical energy. Huge wind farm have large number individual wind turbines which are connected to power transmission network. Around 83 countries in the world are using wind energy for supplying grid and India ranks 5th in the world for the producing electrical energy from wind power(6).

Several hybrid 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 multiinput 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 fusion of the buck and buck-boost converter. The systems in literature require passive input filters to remove the high frequency current harmonics injected into wind turbine generators [6].The harmonic content in the generator current decreases its lifespan and increases the power loss due to heating [6].

In this paper, an alternative multi-input rectifier structure is proposed for hybrid wind/solar energy systems. Theproposed design is a fusion 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 for PFC [7]-[8]; 2) it can support step up/down operations for each renewable source (can support wide rangesof PV and wind input); 3) MPPT can be realized for each source; 4) individual and simultaneous operation is supported.The circuit operating principles will be discussed in this paper. Simulation results are provided to verify with the feasibility of the proposed system. When a source is unavailable or insufficient in meeting the load demands, the other energy source can compensate for the difference. Several hybrid wind/PV power systems with MPPT control have been Proposedanddiscussed 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 multiinput structure has been suggested by [5] that combine the sources from the DC-end while still achieving MPPT

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II.PROPOSED MULTI-INPUT RECTIFIER STAGE

A system diagram of the proposed rectifier stage of hybrid energy system is shown in Figure 2, where one of the inputs is connected to the output of the PV array and the other input connected to the output of a generator. 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. Figure 3 illustrates the case when only the wind source is available. In this case, *D*1 turns off and *D*2 turns on; the proposed circuit becomes a SEPIC converter and the input to output voltage relationship is given by (1). On the other hand, if only the PV source is available, then *D*2 turns off and *D*1 will always be on and the   circuit becomes a Cuk converter as shown in Figure 4.The input to output voltage relationship is given by (2). 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.

$$\frac{V_{dc}}{V_W} = \left(\frac{d_2}{1-d_2} \right)$$

$P = (\rho A C_p V^3) / \lambda \text{(1)}$

Where P is the power generated by wind turbine, ρ is the air density; C_p is the Power coefficient which describes the fraction of the wind captured by the wind turbine. Fig. 1 shows a steady wind speed – power curve, which shows the regulated power achievable from the wind turbine. It is seen that at very low speeds the generated power is very less to be utilized. To allow the turbine to transfer a maximum available wind power for fluctuating wind velocities incident upon the turbine blades, it is desirable to maintain the tip – speed ratio at point of maximum power coefficient C_p. Normally in MPPT the production of the reference rotating speed is based on a measurement of the power generated. So the power generated is simpler and more accurate than the measurement of the wind velocity (7).
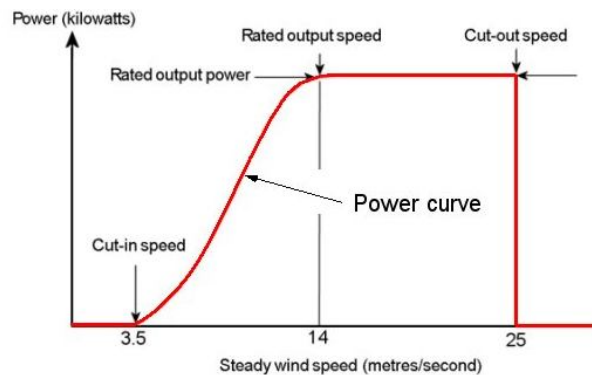

Fig: 1 Power from Wind Turbine

III.SEPIC CONVERTER

Single-ended primary-inductor converter allows electrical potential of output to be greater, less or equal to the input voltage which is controlled by the duty cycle. This converter is similar to buck-boost converter but it has non-inverted output which is an advantage (8). The basic diagram of SEPIC converter is shown in Fig. 2.
 SEPIC converter exchanges energy between capacitors and inductors in order to convert voltage from one level to another level. The amount of converted voltage level is controlled by MOSFET and the SEPIC converter works in two modes.
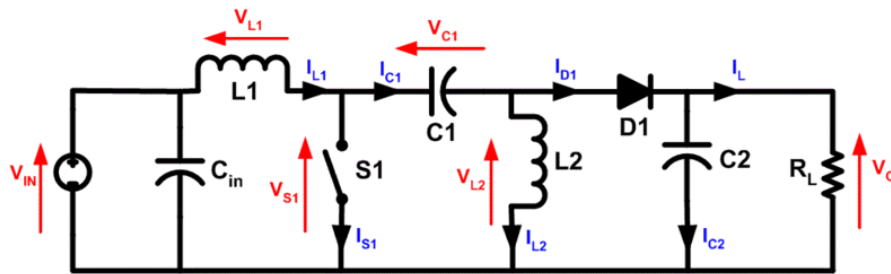
Fig: 1 Basic circuit diagram of SEPIC converter.

A. *Continuous mode*

SEPIC converter is in continuous mode when the current through inductor L1 never falls to zero.

B. *Discontinuous mode*

SEPIC converter is in discontinuous mode when the current through the inductor L1falls to zero.

IV. PROPOSED WORK

The block diagram of the proposed work is shown in Fig. 3, the electrical energy generated by the wind is first converted into DC by rectifier.
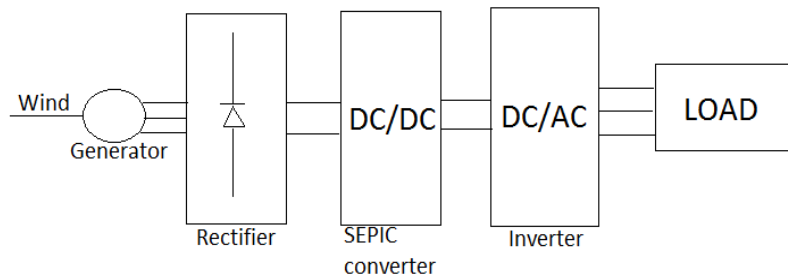

Fig: 2 Basic BLOCK diagram of the proposed work.

The rectified DC is given to the DC/DC SEPIC converter which converts the input voltage to the desired value, either by stepping it up or stepping it down as required by the load. The use of SEPIC converter eliminates the requirement of filter for the unwanted harmonics in the supply. The output of SEPIC converter is given to the inverter which will convert the DC supply to AC. The output of inverter does not have any unwanted harmonics so it is given to the LOAD. The duty ratio of the converter is controlled by the formula

$$V_{dc} = (d / 1 - d) V_w \qquad (2)$$

Where, V_{dc} is the generated output voltage of SEPIC converter,
'd' is the duty ratio, V_w is the voltage generated by the wind source.

V.MPPT CONTROL OF WIND TURBINE

The pitiful drawback of wind system is their intermittent nature of energy source. It is capable of supplying huge amount of power but its presence is highly unpredictable, it can be present in any direction so in order to get maximum efficiency we need to incorporate the MPPT algorithms. The wind power characteristic equation is given by

$$P_m = 0.5\rho A C_p(\lambda, \beta) V^3 \quad (3)$$

Where, $C_p(\lambda, \beta)$ is the power coefficient function and β is the pitch angle.

The power coefficient is dependent on the TSR λ (tip speed ratio) and the pitch angle β. Mathematically TSR is given by

$$\lambda = R W_b / V \quad (4)$$

Where, R is the turbine radius and W_b is the angular rotational speed. Fig 4 and 5 shows the power coefficient curve and power curve for a typical fixed pitch i.e. $\beta = 0$
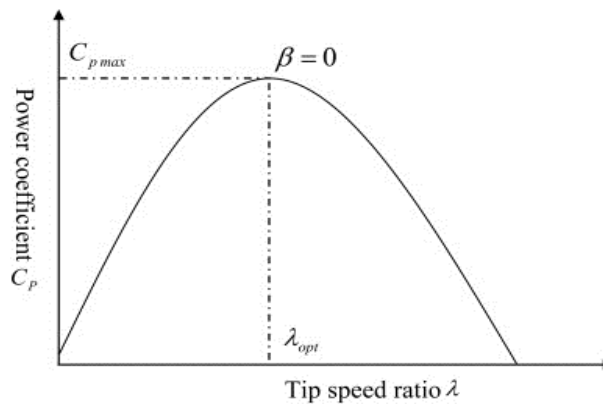

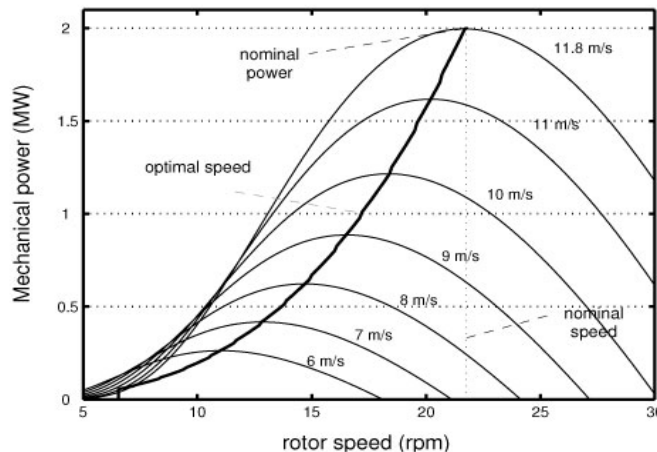Fig: 3 Power coefficient curve for a typical wind turbine

Fig: 4 Power curve for typical wind turbine.

V. RESULT AND DISCUSSION

The proposed work discussed above is simulated using MATLAB software and the following outputs are extracted from the simulation. Fig 6 shows the injected three phase current from the wind source. This current is then given to the SEPIC converter.
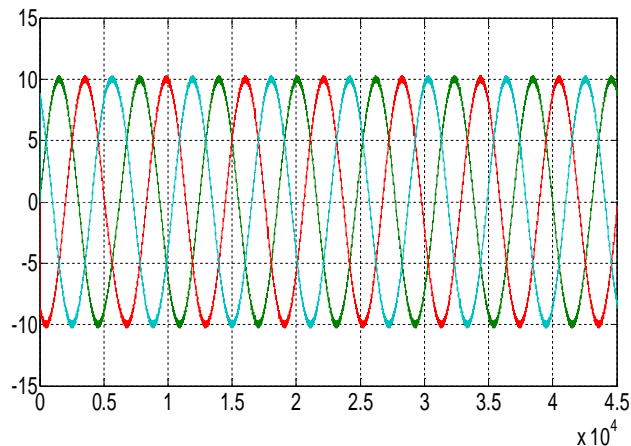

Fig: 5 Injected three phase current of Wind Turbine Generator

Fig 7 & 8 shows the output power and switch current (MOSFET) of SEPIC converter. From power curve we can see that maximum power point has been tracked and maximum power has been achieved which is 1.8W.
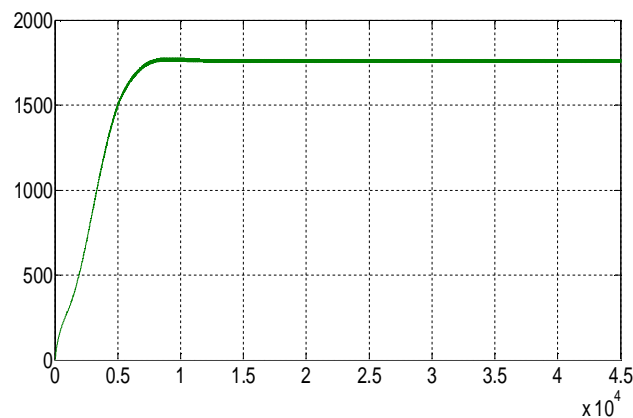

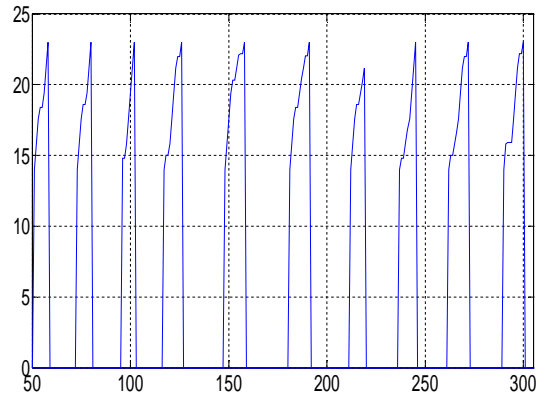Fig: 6 Output power curve of Wind Turbine Generator.
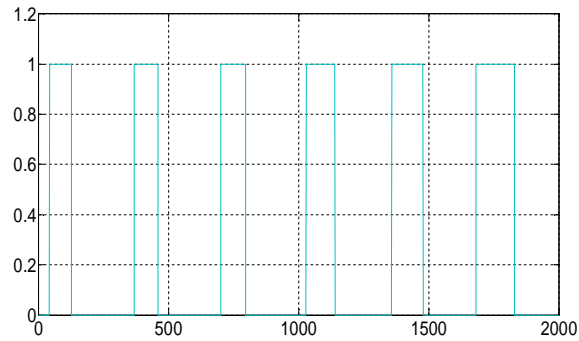
Fig: 7 MOSFET current of SEPIC converter

Fig: 8 Generated pulses to the Inverter connected before load

Fig 9 shows the generated pulse for the inverter in order to get the desired output. Fig 10 shows the FFT analysis of the current and it has been that there no other harmonic component present in the system expect fundamental and THD is 0.44%.
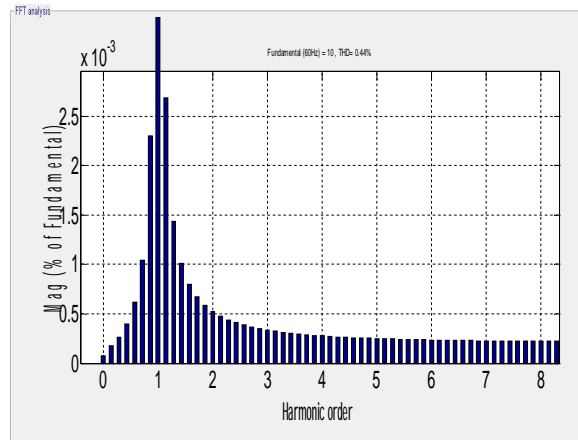

Fig: 10 Total Harmonic Distortions

VI. CONCLUSION

In this paper a new rectifier stage topology with SEPIC converter is presented and it has been seen that after obtaining the MPPT from the wind turbine the SEPIC converter can be used to meet the load demand. The use of SEPIC converter is to reduce the cost of the system since there is no use of high frequency filters because the harmonics content in the system is eliminated the SEPIC converter and it has been seen that the Load demand of 1.8 kW can be achieved without any interruption and the total harmonic content in the system is limited to 0.44%.

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