Performance Analysis of Zeta Converter in Wind Power Application

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Article Received: 28 March 2017 *Article Accepted: 08 April 2017* *Article Published: 13 April 2017*

ABSTRACT

This project proposes the performance analysis of zeta converter in wind power application. The proposed configuration consists of wind power generator, a medium-voltage permanent magnet synchronous generator connected to a low-cost passive rectifier, a DC-DC converter, and an onshore current source inverter. To ensure reliability, safety, and to provide maximum efficiency to the wind power system, selection and design of power electronic converters is very important. The power converter is interfaced between wind generator and load. The Reference voltage is fixed based on the open circuit voltage available at the output of the converter. The benefits of zeta converter over other converters include non-pulsating output current, lower settling time, adaptability, etc. In order to satisfy load voltage ripple requirement, and because of the non-pulsating output current, zeta converter permits the use of small output capacitor. The main aim of this paper is to maintain the constant output voltage, irrespective of change in wind speed. Change in speed, causes the change of output voltage from wind power generator, which causes the duty cycle (D) to vary. Change in duty cycle makes the zeta converter to operate either in boost or buck mode.

Keywords: Wind speed, Permanent magnet synchronous generator, Duty cycle and Zeta converter.

1. INTRODUCTION

Over the past few years the research into the renewable sources likes wind, hydro power plant and photovoltaic cell. Wind energy conversion is one of the best solution to meet the power requirement in remote areas. Now a days the research into the small wind turbine is increased because it have more efficient to produce electricity and cost wise it is less.

Wind source is one of renewable energy so it does not have any fuel cost. It is suitable for the standalone system. Depend on wind speed electrical energy is produced so depend on the load variation and wind speed we can obtain the maximum power from the wind energy conversion. Permanent magnet synchronous generator is used in this system to convert the mechanical energy which is obtained from the wind generator. PMSG is mostly used due to its size and mainly it does not require any external supply to start.

In this system PMSG is connected to the rectifier and Zeta converter, which is used for AC to DC conversion. Our source is wind energy so wind speed is not constant consequently output also will not be constant. For this reason, the fluctuation of the wind power results in fluctuated power output from the wind turbine generator. From the view point of utilities, due to the variation of the generator output, it's not appropriate for the generator to be directly connected to the power grid. In order to reach the condition that the generator output power is suitable for grid-connection, it is essential to use a controller to handle the output produced by the wind turbine generator.

All Renewable Energy Systems require exact power electronic converters. Since the power electronic converter is the heart of the whole system, so, proper design is important. Any early failure or wrong design will make the whole system no longer exist. Since there are different power electronic converters like Buck boost, SEPIC, Cuk etc, the reason which motivated us to use with zeta converter, because of the advantages like adaptability, less switching stress can be interfaced with high frequency transformers, and low settling time.

A. WIND TURBINE CONFIGURATION

The proposed wind energy conversion system supplies 230v/50Hz to the utility sides. It consists of following equipment (1) direct driven PMSG (2) rectifier and zeta converter (for AC to DC conversion) (3) resistive load. The wind energy from the wind turbine is converted into mechanical energy by the rotation of wind turbine rotor. The wind turbine is cannot extract the power completely. Only 59% of the energy can be obtain from the theoretical calculation. Real power coefficient from the turbine is 39% of energy is obtained.

The 2kW wind turbine is connected with the wind generator. The mechanical energy from the wind turbine is converted into electrical energy. Energy produce from the permanent magnet synchronous generator is AC. Again the AC is converted in dc by using AC to Dc converter. Rectifier circuit is used to convert AC to DC. The dc output is given to the zeta converter which provides required dc voltage. The dc voltage is stored in the energy storage device through the single phase inverter to the load. The output voltage of our system should be stay constant for various speed and load condition. Wind speed will be at high and low speed. When the wind speed is too high at the condition means output power will be stored in battery.

At high wind speeds the turbine control system which is used for production. It is same for condition when the battery is fully charged and another condition is load shedding is used at the low wind speed to keep the frequency at the rated value.

Asian Journal of Applied Science and Technology (AJAST)
Volume 1, Issue 3, Pages 199-203, April 2017

The single phase inverter is used for the storage system. It is used to convert the dc to ac. The single phase inverter is used for power transfer.

B. PMSG

The PMSG model is derived from the two phase synchronous reference frame it has two axis q-axis and d-axis. The q-axis is 90 ahead of the d-axis depend on the rotation. The PMSG mathematical modeling is given below q are the two physical quantities derived from the rotation where Ra-armature resistance ωe – electrical rotating speed which is related to the mechanical rotating speed of the generator; as $\omega e = np.\omega g$, where np is the number of poles pairs; and ΨPM is the magnetic flux of the permanent magnets. The electromagnetic torque of the PMSG is given below Dynamic modeling of PMSG q-axis is 90° ahead of direct axis with respect to direction of rotation:

$$d\left(\frac{id}{dt}\right) = -\left(\frac{Ra}{la}\right)id + \omega e\left(\frac{Lq}{Ld}\right)iq + \left(\frac{1}{Ld}\right)vd$$

Put Ld=L

$$d\left(\frac{id}{dt}\right) = -\left(\frac{Ra}{L}\right)id + \omega e(L/L)iq + (1/L)vd$$

$$d\left(\frac{id}{dt}\right) = -\left(\frac{Ra}{L}\right)iq + \omega e\ iq + (1/L)vd$$

$$d\left(\frac{id}{dt}\right) = -\frac{Ra}{Lq}iq - \omega e\left(\frac{Ld}{Lq}id + \frac{1}{Ld}\Psi PM\right) + \frac{1}{Lq}iq$$

$$d\left(\frac{id}{dt}\right) = -\frac{Ra}{L}iq - \omega e\left(id + \frac{1}{L}\Psi PM\right) + \frac{1}{L}iq$$

Let $\omega e = np.\omega g$

$$Te = 1.5[(Ld - Lq)idiq + \Psi PMiq)]$$

Put Lq=L

$$Te = 1.5np\Psi PMiq$$

Where

Ra=armature resistance

ωe = Electrical rotating speed which is related to the mechanical rotating speed of the generator

np=number of poles pairs

ΨPM =magnetic flux of the permanent magnets

BUCK-BOOST	CUK	SEPIC
No boosting operation	Difficult to control for slow varying applications	Complex compensatory circuit is needed to make the converter operate properly
Switching action of transistors create a high current ripple in input capacitors	A capacitor with high capacitance current handling capacity is required since the sepic converter transfer all its energy through the series capacitor	This complex compensation circuit slows down the performance of the converter
Pulsed output action of transistors create a high current ripple	Like the buck boost, sepic has pulsating output current	Difficult to stabilize
Buck boost mode has higher switching and inductor current than boost mode	Only boost, no buck operation is performed	Require capacitor with larger ripple handling capability

C. DESIGN OF POWER CONVERTER

Power converters play a main role in the process, which is the heart of the entire system. It is installed between the source and load.

Duty cycle

Assuming 100% efficiency, the duty cycle, D, for a ZETA converter operating in CCM is given by

$$D = \frac{Vout}{Vin + Vout}$$

This can be rewritten as

$$\frac{D}{1-D} = \frac{Iin}{Iout} = \frac{Vout}{Vin}$$

Dmax occur at Vin (min) and Dmin occur at Vin(max)

Zeta Converter

The zeta converter is capable of converting input voltage in to a non-inverted output voltage, having either a lower or higher value than input voltage. It is capable of operating in both continuous and discontinuous modes of operation. The zeta converter consists of components like power electronic switch (S), inductors (L1 and L2), a diode, capacitors (C1 and C2), and a load (R).

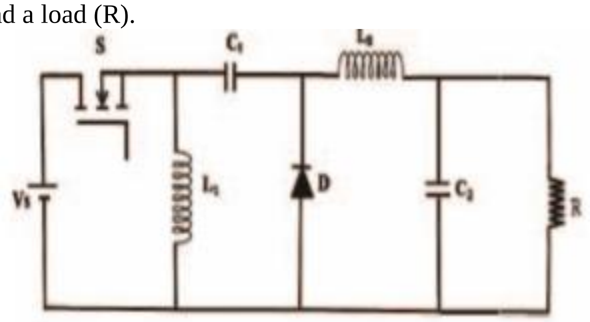

Figure 1: Basic circuit diagram of zeta converter

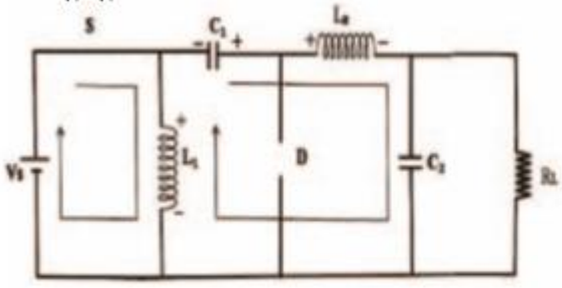

Figure 2: Zeta converter during mode 1 operation

Mode 1: This mode is achieved, when the diode (D) is off and switch(S) is on. The current through the inductor L1 and L2 are drawn from the source Voltage Vs. The Inductor current iL1 and iL2 increase linearly. This mode of operation is also called charging mode.

Mode 2*:* This mode is achieved, when the diode (D) is in ON state and switch (S) is off. The energy stored in the inductors discharges and transferred to the load. The current in the inductors decreases linearly. This mode of operation is also called discharging mode.

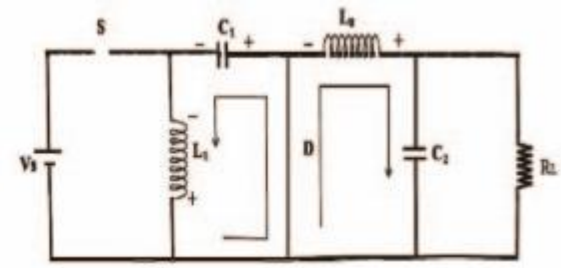

Figure3: Zeta converter for mode 2 operation

CONTINUOUS CONDUCTION MODE

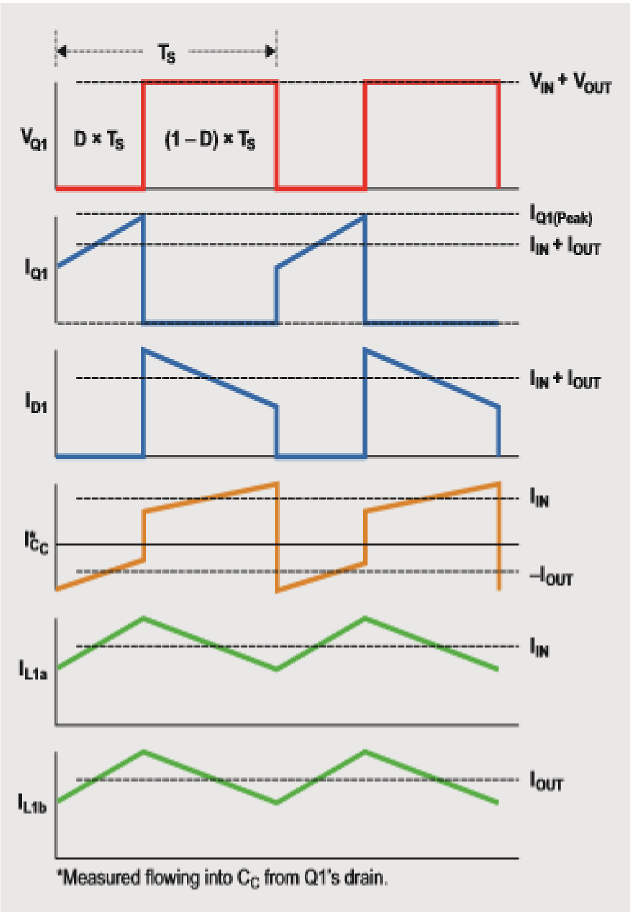

Figure 4: Waveform of zeta converter during CCM operation

2. SIMULATION

The SIMULINK Model for wind energy conversion and Zeta converter is made in MATLAB. The output voltage from the wind generator is given as one of the inputs to duty cycle, which is given to Zeta converter. Also, the output voltage from the rectifier after conversion it as a dc input from the wind power generator is serves as the input to Zeta converter.

The MATLAB SIMULINK consists of wind power system with pmsg motor, along with Zeta converter.

SIMULATION DIAGRAM

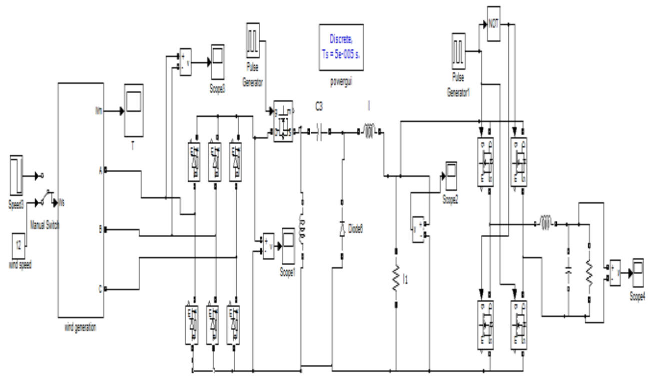

Figure 5: simulation of proposed system

AC INPUT VOLTAGE WAVEFORM

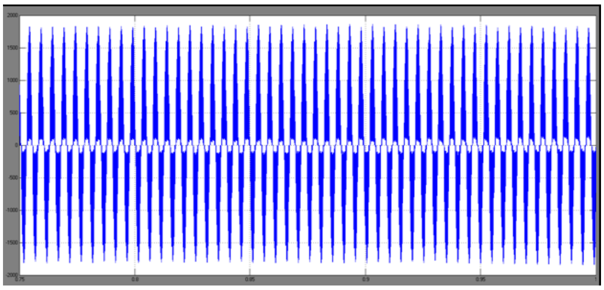

Figure 6: Ac input voltage waveform, Where X axis shows time and Y axis shows voltage

RECTIFIER OUTPUT VOLTAGE

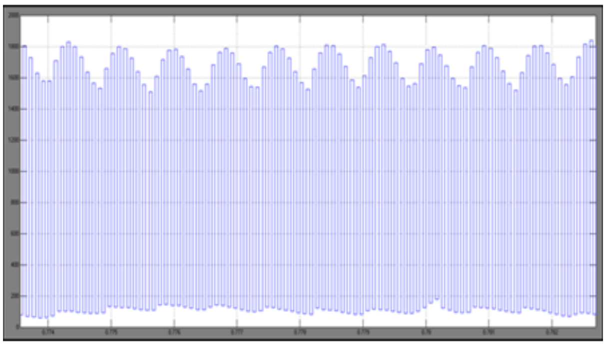

Figure 7: Rectifier output voltage waveform, Where X axis shows time and Y axis shows voltage

OUTPUT VOLTAGE WAVEFORM

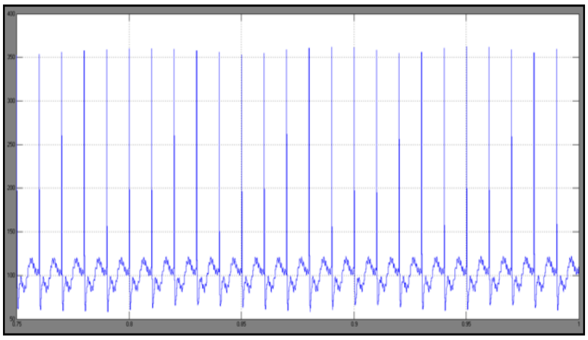

Figure 8: Output voltage waveform, Where x axis shows time and Y axis shows voltage

HARDWARE DIAGRAM

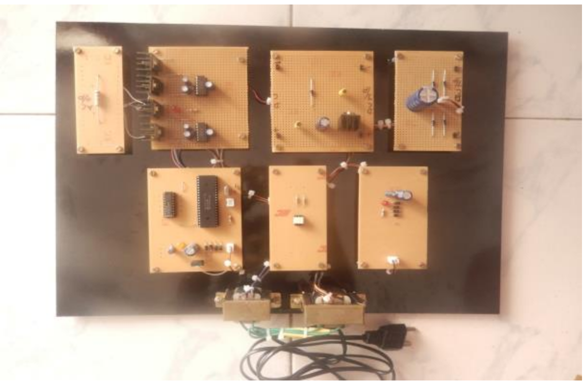

Figure 9: Hardware Diagram

BOOSTED DC VOLTAGE

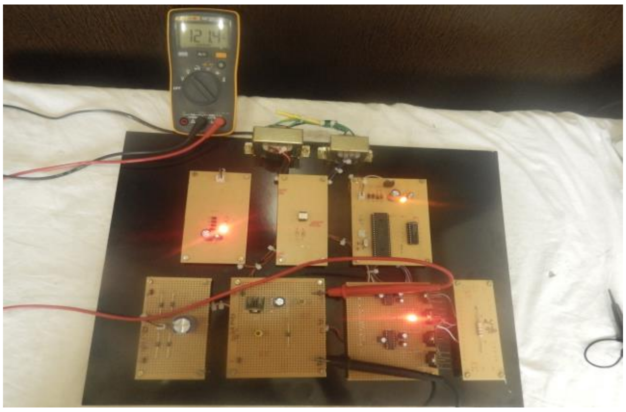

Figure 10: Boosted dc voltage hardware diagram

BOOSTED DC VOLTAGE WAVEFORM

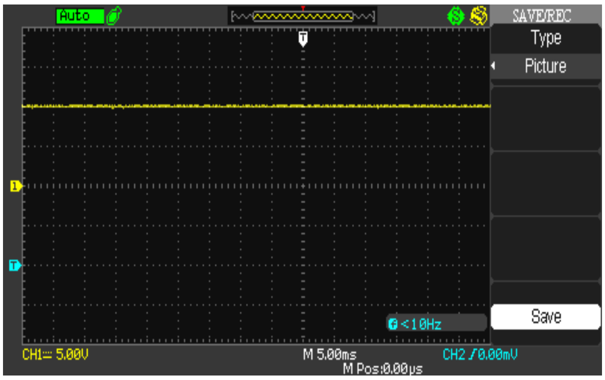

Figure 11:Boosted dc voltage waveform

INPUT AC VOLTAGE

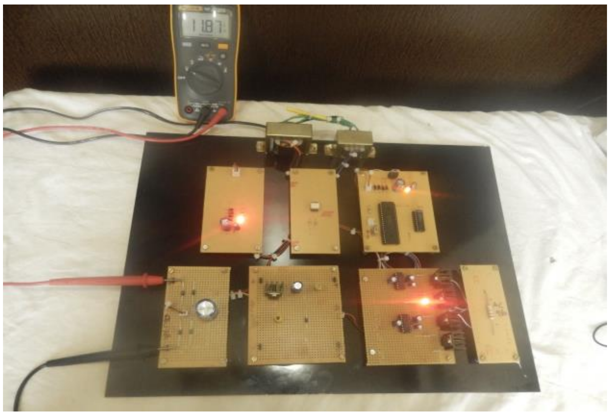

Figure 12: Input ac voltage hardware diagram

INPUT AC VOLTAGE WAVEFORM

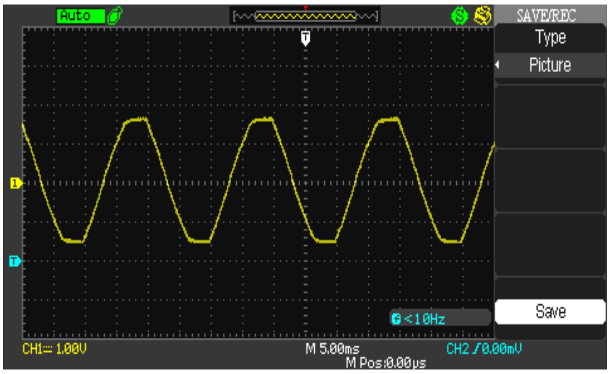

Figure 13: Input ac voltage waveform

OUTPUT AC VOLTAGE WAVEFORM

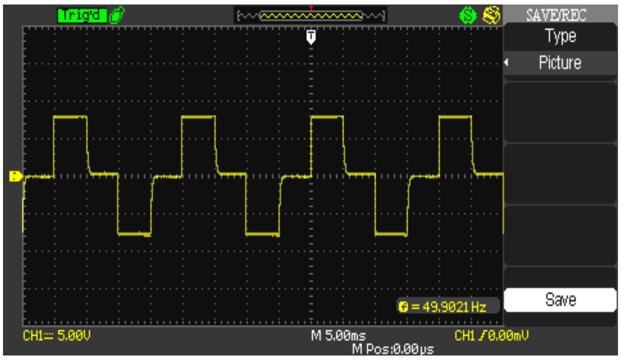

Figure 14: Output ac voltage waveform

3. CONCLUSION

A control of single phase standalone wind based energy sources has been analyzed in the paper. The purpose of the zeta converter is to maintain the constant output voltage across the load under different speed conditions. Making use of zeta converter, the ripple is reduced, as it can be inferred from the above graphs. The Zeta converter operates based on the duty cycle. Lower the value of duty cycle, buck operation will be performed and higher the value of duty cycle, boost operation will be performed by the Zeta converter. The future scope of this paper can be further expanded by using MPPT Algorithm.

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