DESIGN OF ZETA CONVERTER And COMPARISON OF FILTERS

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***Abstract*—This paper proposes about the Design of Zeta converter and with different types of filter. In the world of switching DC/DC converters the Zeta topology is a lesser known relative of the SEPIC topology. A Zeta converter is a fourth order DC-DC converter made up of two inductors and two capacitors and capable of operating in either step-up or step-down mode. The need for different types of filters is to remove unwanted or undesired frequency from the signal. It will perform the selection of partials according to the frequency that we want to reject, retain or emphasize. In other words, the filter will modify the amplitude of the partials according to the frequency. As we can say filter is a linear transformation. In this paper we are going to see about the simulation of zeta converter with some types of filter.**

Keywords—Zeta converter, Fourth-order, filters, linear transformation.

I. INTRODUCTION

Similar to the SEPIC DC/DC converter topology, the ZETA converter topology provides a positive output voltage from an input voltage that varies above and below the output voltage [1]. The ZETA converter also needs two inductors and a series capacitor, sometimes called a flying capacitor. Unlike the SEPIC converter, which is configured with a standard boost converter, the ZETA converter is configured from a buck controller that drives a high-side PMOS FET. The ZETA converter is another option for regulating an unregulated input power supply, like a low-cost wall wart. To minimize board space, a coupled inductor can be used. This article explains how to design a ZETA converter [2].

A Zeta converter performs non-inverting buck-boost function similar to that of a SEPIC, which is an acronym for Single-Ended Primary Inductance Converter. The Zeta topology is also similar to the SEPIC, in that it uses two inductors, two switches and a capacitor to isolate the output from the input. However, Zeta conversion requires a P-Channel MOSFET as the primary switch, while SEPIC conversion uses an N-Channel MOSFET. This architecture makes SiPix's SP6125/6/7 controllers suitable for use in a Zeta topology [3-5].

The conventional technique of AC-DC conversion using a diode rectifier with bulk capacitor is no longer in use due to numerous problems such as low order harmonics injection into AC power supply, high peak current, low power factor, line voltage distortion, increased electromagnetic interference, extra burden on lines, and additional losses[6]. Solid-state switch mode rectification converters have reached a matured level for improving power quality in terms of power-factor correction (PFC) and reduced total harmonic distortion (THD). The major challenge is to control the output voltage and improve PFC simultaneously [7-8]. The basic DC to DC converter topologies using Buck-converter, Boost converter and Buck-Boost converter have their intrinsic limitations when used for active power factor correction along with voltage regulation purposes. The above literature does not deal with the comparison of filters.

In the proposed model a relatively new class of DC-DC converter, Zeta converter is used for active PFC and voltage regulation having advantages of being naturally isolated structure, can operate as both step up/down voltage converter and having only one stage power processing for both voltage regulation and Harmonics.

A Zeta converter performs non-inverting buck-boost function similar to that of a SEPIC. But in application which implies high power, the operation of a converter is not attractive in discontinuous conduction mode because it results in high rms values of the currents causing high levels of stress in the Semiconductors. In conventional methods, an active power factor correction (PFC) is performed by using a Zeta converter operating in continuous conduction mode (CCM), where the inductor current must follow a sinusoidal voltage Waveform. This method provides nearly unity power factor with low THD.

The term filter can have a large number of different meanings. In general it can be seen as a way to select certain elements with desired properties from a larger set. Any linear operation could be said to be filters but this world go far beyond the scope of digital audio effects. It is possible to demonstrate what a filter is by using one's voice and vocal tract.

II. MODE OF OPERATION

A. Basic principles of Zeta converter

When analyzing Zeta waveforms it shows that at equilibrium, L_1 average current equals I_{IN} and L_2 average current equals I_{OUT}, since there is no DC Current through the flying capacitor C_{fly}. Fig 2.1 shows the circuit diagram of Zeta converter.

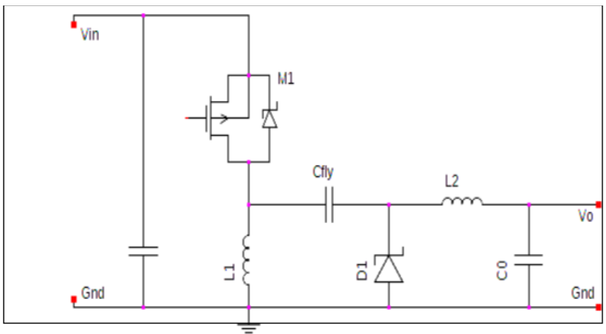

Fig: 2.1 Circuit diagram of Zeta converter

The Zeta converter is also called inverse-SEPIC. It has the capability of both Buck and Boost operation. It has an advantage of reducing the voltage ripple and obtaining a stable response output voltage.

B. Stage 1: MOSFET ON

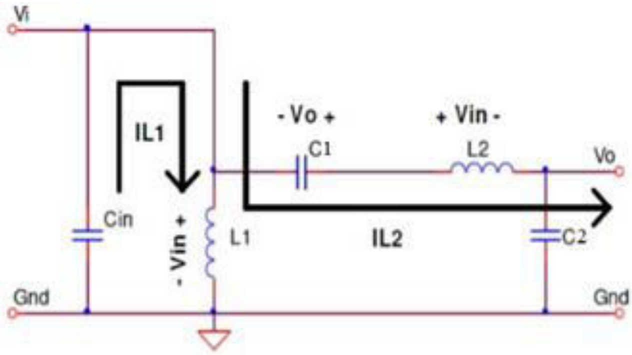

Fig: 2.2 Mosfet ON state

The switch M_1 is in ON state, so voltages V_{L1} and V_{L2} are equal to V_{in}. In this time interval diode D_1 is OFF with a reverse voltage equal to - (V_{in} + Vo). Inductor L_1 and L2 get energy from the voltage source, and their respective currents I_{L1} and I_{L2} are increased linearly by ratio Vin/L_1 and Vin/L_2 respectively. Consequently, the switch current $I_{M1}=I_{L1}+I_{L2}$ is increased linearly by a ratio Vin/L, where $L=L_1.L_2/(L_1+L_2)$. At this moment, discharging of capacitor C_1 and charging of capacitor C_2 takes place. Therefore, C_1 sees ground potential at its left side and V_{OUT} at its right from the above results, it is concluded that when the magnitude of the input carrier frequency is reduced, it is possible to reduce the SPWM carrier frequency to a good extent using Direct Digital Frequency Synthesizer (DDFS).

C. Stage 2: MOSFET OFF

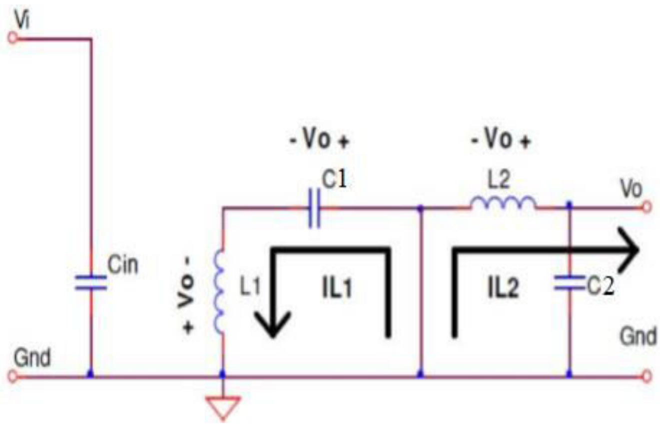

Fig: 2.3 Mosfet Off state

In this stage, the switch M_1 turns OFF and the diode D_1 is forward biased starting to conduct. The voltage across L_1 and L_2 become equal to -Vo and inductors L_1 and L_2 transfer energy to capacitor C_1 and load respectively. The current of L_1 and L_2 decreases linearly now by a ratio $-V_0/L_1$ and $-V_0/L_2$, respectively. The current in the diode $I_{D1}=I_{L1}+I_{L2}$ also decreases linearly by ratio $-V_0/L$. At this moment, the voltage across switch M_1 is V_M= Vin + V_0. Figure 4 shows the main waveforms of the ZETA converter, for one cycle of operation in the steady state continues mode

III. DESIGN OF ZETA CONVERTER

A. Duty Cycle

A ZETA converter performs a non-inverting buck-boost function. For a ZETA converter operating in CCM, the duty cycle is defined as

$$D = V_0 / V_{in} + V_{out} \quad (1)$$

where V_0 is the dc link voltage, V_{in} is the rms value of input voltage, D is the duty cycle

B. Inductor Selection

To determine the value of inductances L_1 and L_2 the peak-to-peak ripple current is taken approximately 10-20% of the average output current. The value of these inductances may be expressed as,

$$L_1 = L_2 = 1/2 * (V_{in}.D)/(\Delta I_{L(PP)}.f_{sw}) \quad (2)$$

where f_{sw} is the switching frequency, ΔI_L is the peak to peak current

C. Capacitor Selection

The coupling capacitor (C_1) is designed on the basis of its ripple voltage. The maximum voltage handled by a coupling capacitor (C_1) is equal to input voltage. It can be estimated as

$$C = \frac{I_0 D}{\Delta V_C 0(0.5F_S)} \quad (3)$$

The output capacitor (C_2) must have enough capacitance to maintain the dc link voltage and must have to provide continuous load current at high switching frequency. It can be calculated as:

$$C_2 = \frac{I_0 D}{\Delta V_C 0(0.5F_S)} \quad (4)$$

where, I_o is output rated current, F_s is switching frequency, V_{c1} is the ripple voltage of the coupling capacitor, V_{co} is the ripple voltage of the output capacitor.

IV. DIFFERENT TYPES OF FILTER

The circuits are simulated in MATLAB/SIMULINK with different types of filters. The need to go for different types of filter is to remove the undesired and unwanted frequency from the signal. Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

A. Simulation of Zeta converter with C filter

The Zeta converter is simulated with R load and C filter. The C filter is also called as π filter since it contains only one capacitor whose shape is Pi. The C filter contains many advantages such as the conduction angle is higher in diodes than the circuits where the capacitor is fed directly, so the ratio of peak current through the diodes to the current supplied to the load is lower. It also has good regulation and better ripple reduction. The Fig 3 shows the simulink model of Zeta converter with C filter.

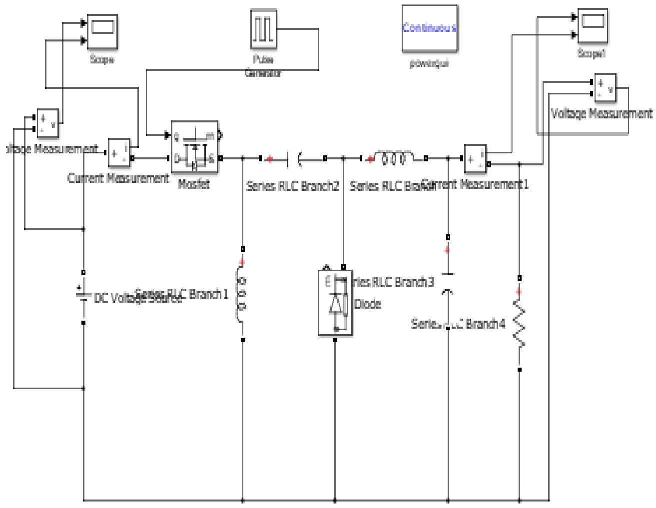

Fig 3 Simulink model of Zeta converter with C filter

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The above simulink model is simulated in MATLAB. Fig 3.a and 3.b shows the output voltage and current of Zeta converter with C filter

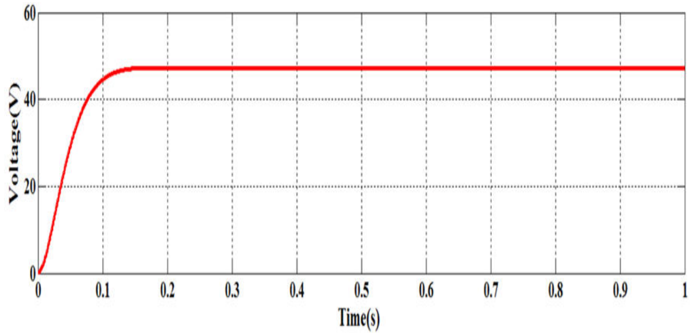

Fig 3.a Output voltage of Zeta converter with C filter

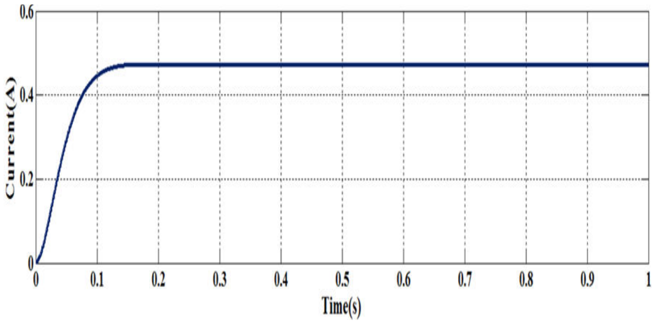

Fig 3.b Output current of Zeta converter with C filter

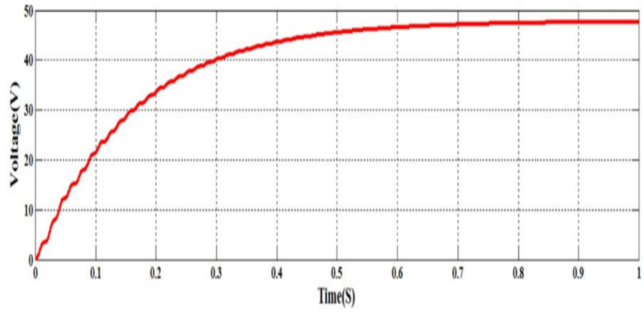

Fig 4.a Output voltage of Zeta converter with T filter

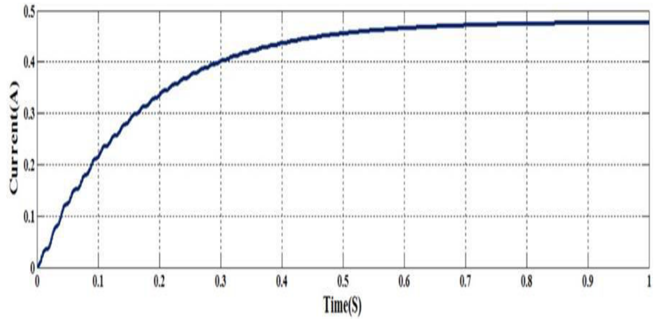

Fig 4.b Output current of Zeta converter with T filter

B. Simulation of Zeta converter with T filter

Three-element filters can have a 'T' or 'π' topology and in either geometries, a low-pass, high-pass, band-pass or band-stop characteristic is possible. The components can be chosen symmetric or not, depending on the required frequency characteristics. The high pass T filter in the illustration, has a very low impedance at high frequencies, and a very high impedance at low frequencies. That means that it can be inserted in a transmission line, transmitting low frequencies and reflecting high frequencies being passed and low frequencies being reflected. Fig 4 shows the simulink model of Zeta converter with T filter.

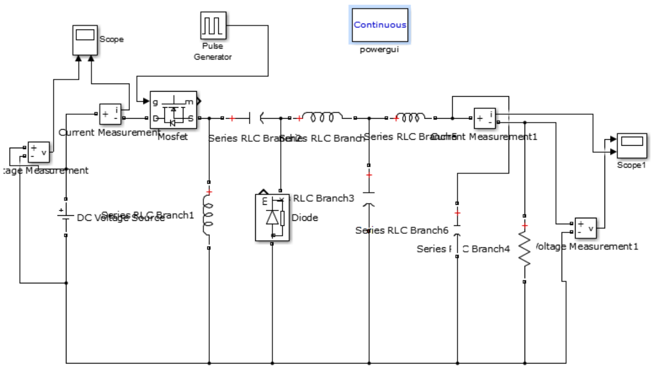

Fig 4 Simulink model of Zeta converter with T filter

The above simulink model is simulated in MATLAB and fig 4.a shows the output voltage and current of Zeta converter. The ripple content is greater in T filter when compared to C filter.

C. Simulation of Zeta converter with PI filter

A PI filter is used to attenuate noise in power and signal lines. This demonstration shows the output voltage from a DC power supply with a Pi filter, which consists of an inductor (choke) between a pair of capacitors.

Pi filter consist of a shunt capacitor at the input side and it is followed by an L-section filter, since it has capacitor at the input side it is called as Capacitor Input filter. The output from the rectifier is directly given across capacitor. The pulsating DC output voltage is filtered first by the capacitor connected at the input side and then by the choke coil and then by another shunt capacitor. The ultimate aim of a filter is to achieve ripple free Dc voltage. The filters we have discussed before are also efficient in removing Ac ripples as it consists of one more capacitor at the input side.

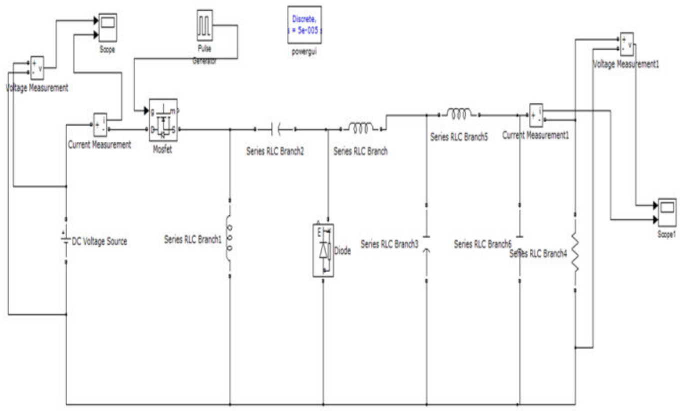

Fig 5 Simulink model of Zeta converter with PI filter

The above model is simulated in MATLAB. Fig 5.a and 5.b shows the output voltage and current of Zeta converter with PI filter. The ripple content is very low in Pi filter when compared to others.

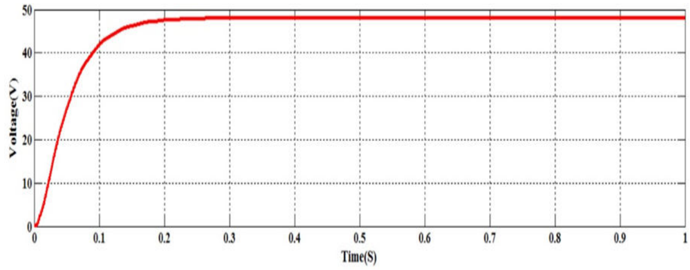

Fig 5.a Output voltage of Zeta converter with Pi filter

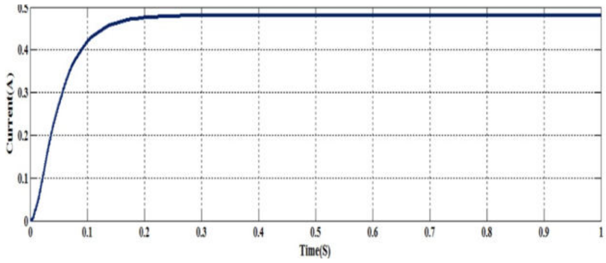

Fig 5.b Output current of Zeta converter with PI filter

D. Simulation of Zeta converter with LC filter

An LC circuit, also called a Resonant circuit, tank circuit or tuned circuit, is an electric circuit consisting of an inductor, represented by the letter L and a capacitor, represented by the letter C, connected together. The circuit can act as an electrical resonator, an electrical analogue of a tuning fork, storing energy oscillating at the circuit's resonant frequency.

LC circuits are used either for generating signals at a particular frequency, or picking out a signal at a particular frequency from a more complex signal, this function is called a Bandpass filter. Here we have used series LC filter. The ripple is more in LC filter when compared to other filters. Fig 6 shows the simulink model of Zeta converter with LC filter

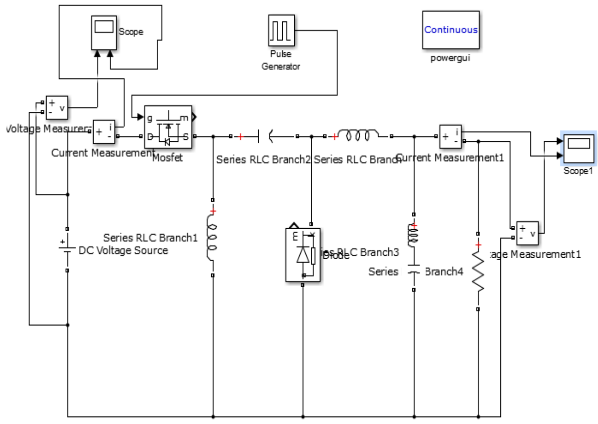

Fig 6 Output voltage of Zeta converter with LC filter

The above simulink model is simulated in MATLAB where the Fig 6.a and 6.b shows the output voltage and current of Zeta converter with LC filter.

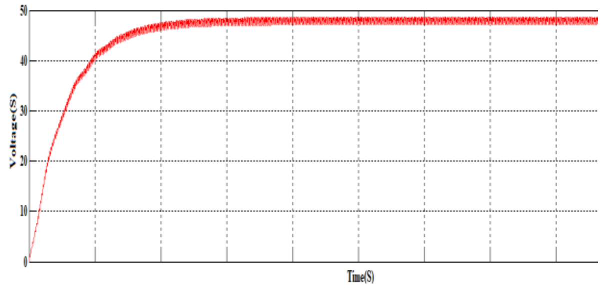

Fig 6.a Output voltage of Zeta converter with LC filter

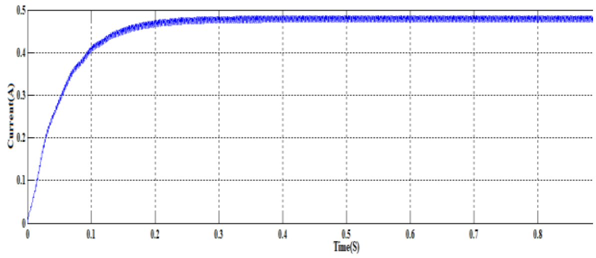

Fig 6.b Output current of Zeta converter with LC filter

Now, the comparison of different types of filters is tabulated. The ripple content in each filters are compared with other filters. Thus, the table 1 shows the comparative results of different types of filter.

TABLE 1. COMPARISON OF FILTERS

TYPES OF FILTER	RIPPLE CONTENT
C filter	0.094
T filter	0.834
PI filter	0.001
LC filter	1.854

Thus the PI filter has very low ripple content when compared to all other filters. Thus the table1 shows us that the Zeta converter with PI filter has many advantages than any other filters.

VI. CONCLUSION

. Mathematical analysis of Zeta converter is carried out for design values of the capacitor and inductor. With the help of Zeta converter we can achieve a non-inverted output, stable output response is obtained and it also proves to be effective. The circuit losses are very less when compared to the other converters. Filtering is still one of the most commonly used effect tool for sound recording and production. Neverthless, its successful application is heavily dependent on the specialized skills of the operator. Thus Zeta converter with different types of filters is compared and their ripple content is tabulated. Therefore the Zeta converter with PI filter have very low ripple when compared to other filters and the proposed converter can be applied to wind energy conversion system

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