PFC in Real Time Environment using NCA with Converter (Z)

A. Sangeetha[1] K. S. Sridharan[2] L. Umasankar[3] N. Kalaiarasi[4] N. Hariharan[5]
[1]U.G Student [2]Chief Executive Engineer [3,5]Assistant Professor [4]Professor & Head
[1,3,4,5]Department of Electrical & Electronics Communication Engineering
[1,3,4,5]R.M.K College of Engineering and Technology, Puduvoyal, Chennai-601 206 [2]LUCAS TVS Ltd.

Abstract— A zeta converter eliminates many of the limitations in the previous version of DC-DC converters like sepic, buck and buck-boost converters. But due to its open loop operation there is discontinuity in the output current whenever there is variation in the load. Due to this discontinuous conduction, power factor is affected at the input supply and hence high RMS values of the currents causes high levels of stress in the semiconductors. Our proposed work increases the power factor near to unity using novel control algorithm. Novel control algorithm(NCA) is a technique in which power factor is corrected using parameters available at the input and the output side of the converter. This technique does not require any separate circuit for power factor correction and it is implemented using a microcontroller.

Key words: Zeta Converter, NCA, PIC micro Controller, PFC, CCM

I. INTRODUCTION

Several topologies have been researched in search of a structure which not only is able to fulfil the requirements of the power factor and the amount of harmonics injected in a line foreseen in the norms, but which would also show the best ensemble of characteristics. The study of model of the pulse-width modulation (PWM) DC-to-DC Zeta converter working in discontinuous conduction mode (DCM)[1]. Later, a single power-conversion AC–DC converter with high power factor and high efficiency with the use of novel control algorithm was proposed. [2]

The implementation of pulse width modulated Zeta converter with better efficiency, lower total harmonic distortion factor and power factor correction was also proposed and the performance of Zeta converter is compared by giving disturbance in both open loop and closed loop [3].

For most actual power applications, power-factor correction (PFC) converters usually operate in the stable continuous conduction mode (CCM), but input current distortion will occur as long as these converters operate in oscillatory condition. Typically, a Zeta PFC converter under the general pulse width modulated (GPWM) control possesses high performance, and requires simpler control circuitry with fewer external components [4].

Also a new single-stage, single-switch power factor correction converter with output electrical isolation was proposed. The topology of this converter is derived by combining a boost circuit and a forward circuit in one power stage. To improve the performance of the AC–DC converter two bulk storage capacitors are adopted [5].

The proposed system is built by finding out disadvantages from this paper like presence of high peak current and affecting the input power factor. The main objective of this project is the development of cost effective ZETA converter for power factor correction in the AC supply.

II. METHODOLOGY

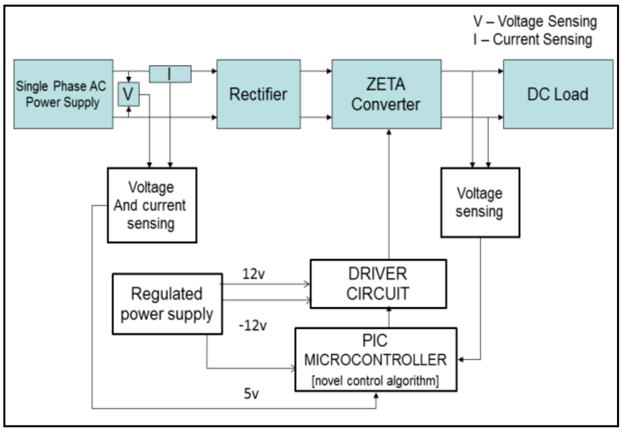

Fig. 1: Proposed Model

Fig.1 represent the proposed model diagram consists of a rectifier which converts input AC supply into DC. The ZETA converter does the buck-boost operation of the DC voltage. The voltage and the current sensors on both the input and output side of the converter senses voltage and current and feeds them to the microcontroller. The microcontroller is programmed with control algorithm to drive the ZETA converter using the driver circuit. This closed loop operation of the ZETA converter does the work of power factor correction in the input AC supply.

A. *Power Supply:*

All the electronic components starting from diode to Intel IC's only work with a DC supply ranging from -+5v to -+12v. We are utilizing for the same, the cheapest and commonly available energy source of 230v-50Hz and stepping down, rectifying, filtering and regulating the voltage. This will be dealt briefly in the forth-coming sections.

B. *Step Down Transformer:*

In our circuit the transformer of 230v/15-0-15v is used to perform the step down operation where a 230V AC appears as 15V AC across the secondary winding. One alteration of input causes the top of the transformer to be positive and the bottom negative. The next alteration will temporarily cause the reverse. The current rating of the transformer used in our project is 2A. Apart from stepping down AC voltages, it gives isolation between the power source and power supply circuitries.

C. *Rectifier Unit:*

A bridge rectifier of four diodes (4*IN4007) are used to achieve full wave rectification. The DC voltage appearing across the output terminals of the bridge rectifier will be somewhat less than 90% of the applied rms value. In this circuit during positive half cycleD1 & D2 will conduct to give 10.8v pulsating DC. The DC output has a ripple frequency of 100Hz. Since each alteration produces a resulting output pulse, frequency = 2*50 Hz. The output obtained is not a pure DC and therefore filtration has to be done.

D. Filtering Unit:

Filter circuits which are usually capacitors acting as a surge arrester always follow the rectifier unit. This capacitor is also called as a decoupling capacitor or a bypassing capacitor and is used not only to 'short' the ripple with frequency of 120Hz to ground but also to leave the frequency of the DC to appear at the output. From fig.2 the load resistor R1 is connected so that a reference to the ground is maintained. C1R1 is for bypassing ripples. C2R2 is used as a low pass filter, i.e. it passes only low frequency signals and bypasses high frequency signals. The load resistor should be 1% to 2.5% of the load. 1000kf/25v can be used for the reduction of ripples from the pulsating. 10kf/25v used for maintaining the stability of the voltage at the load side. 0.1kf/25v used for bypassing the high frequency disturbances.

E. Voltage Regulators:

The voltage regulators play an important role in any power supply unit. The primary purpose of a regulator is to aid the rectifier and filter circuit in providing a constant DC voltage to the device. With a regulator connected to the DC output, the voltage can be maintained within a close tolerant region of the desired output. IC7812 and 7912 is used in this project for providing +12v and –12v DC supply.

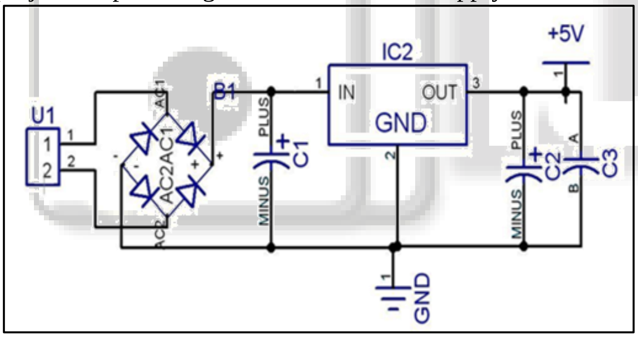

Fig. 2: Rectifier and Filtering Circuit

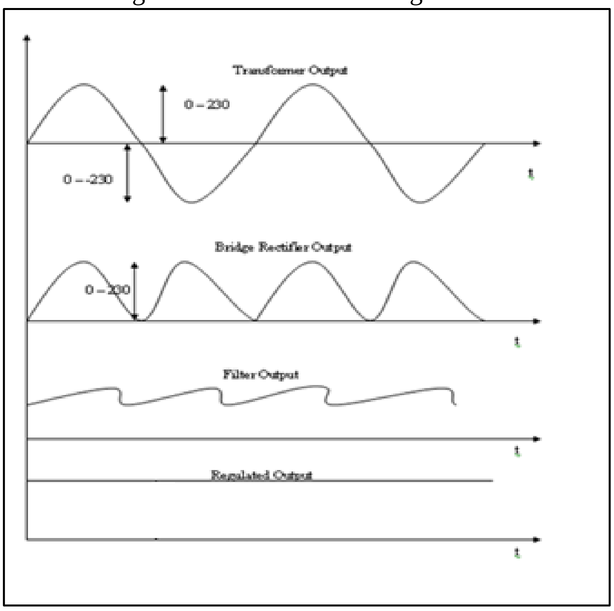

Fig. 3: Wave Form of Regulated Power Supply

III. HARDWARE IMPLEMENTATION

Fig.4 represents hardware of proposed system .The output from the microcontroller is given to the optocoupler.When the light source is emitted, the switch is closed hence becomes short circuited and the output signal is given to the comparator.

When the light source is not emitted the switch is open and the output signal is given to the comparator. The output of the optocoupler is given to the inverting terminal of the comparator and the reference voltage is given to the Non inverting terminal by adjustable voltage regulator.

The comparator compares the voltage and the higher voltage will pass through the comparator. If the inverting terminal output is 1 then the switch is closed and the negative supply passes from the comparator to the push pull amplifier.

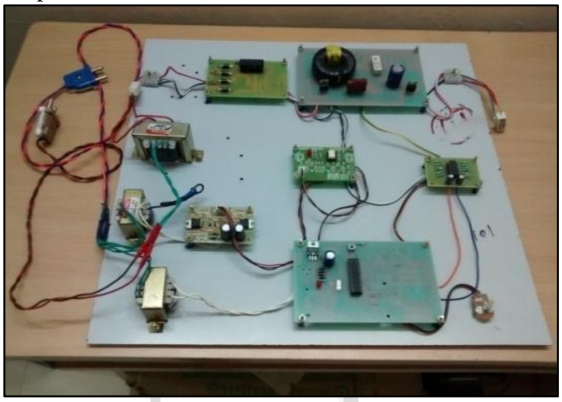

Fig. 4: Hardware of Proposed System

The push pull amplifiers consist of NPN and PNP transistor. If the output of the comparator is positive then the NPN transistor will allow the signal and the LED (red color) will be indicated.

If the output of the comparator is negative then the PNP transistor will allow the signal and the LED (green color) will be indicated. If the positive supply is given to the Gate terminal of the MOSFET then it will be turn ON. The microcontroller is programmed with control algorithm to drive the ZETA converter using the driver circuit. This closed loop operation of the ZETA converter does the work of power factor correction in the input AC supply.

IV. ZETA CONVERTER:

A Zeta converter performs a non-inverting buck-boost function similar to that of a SEPIC.. In this paper, 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.

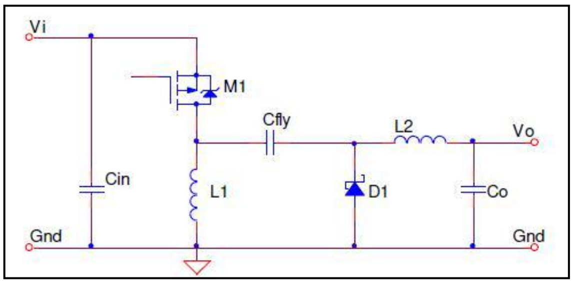

Fig. 5: Switch ON State:

fig.5 and fig.6 explains switching operation. When analysing Zeta waveforms it shows that at equilibrium, L1 average current equals Iin and L2 average current equals Iout, since there is no DC current through the flying capacitor Cfly. Also in the Stage 1[M1ON] Zeta converter during MOSFET ON time the switch M1 is in ON state, so voltages VL1 and VL2 are equal to Vin. In this time interval diode D1 is OFF with a reverse voltage equal to – (Vin + VO). Inductor L1 and L2 get energy from the voltage source, and their respective currents IL1 and IL2 are increased linearly by ratio Vin/L1 and Vin/L2 respectively. Consequently, the switch current IM1=IL1+IL2 is increased linearly by a ratio Vin/L, where L=L1.L2/ (L1+L2). At this moment, discharging of capacitor Cfly and charging of capacitor C0 take place.

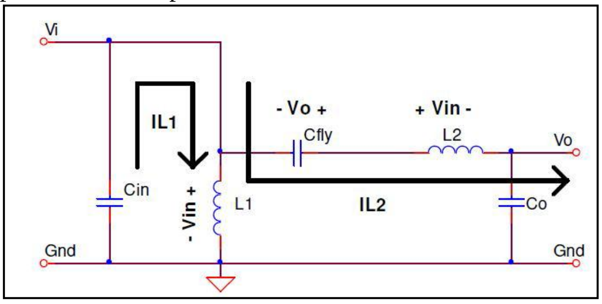

Fig. 6: Switch OFF State:

In this stage, the switch M1 turns OFF and the diode D1 is forward biased starting to conduct. The voltage across L1 and L2 become equal to –Vo and inductors L1 and L2 transfer energy to capacitor Cfly and load respectively. The current of L1 and L2 decreases linearly now by a ratio –V0/L1 and – V0/L2, respectively. The current in the diode ID1=IL1+IL2 also decreases linearly by ratio –V0/L. At this moment, the voltage across switch M1 is VM=Vin + V0. Fig. 3 shows the main waveforms of the ZETA converter, for one cycle of operation in the steady state continuous mode.

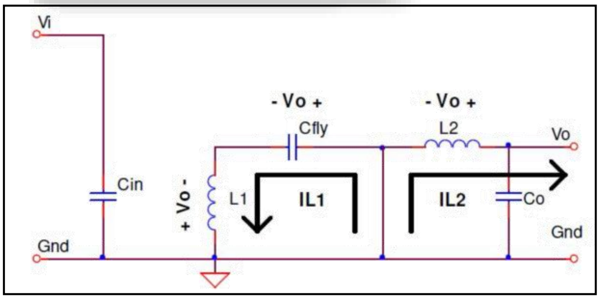

Fig.7: Closed Loop

V. Novel Control Algorithm

In order to obtain a high power factor in the proposed system, it requires the control algorithm for both PFC and output control. To achieve good controllability, the nonlinear system needs to be transformed into the linear system by the feedback linearization. When unity power factor is achieved, the input current i_{in} is a sinusoidal waveform in phase with v_{in} as

$$i_{\text{in}} = I_m \sin \omega t$$

Where I_m is the amplitude of the input current. Assuming that the converter is ideal with no power loss, the instantaneous input power p_{in} and the desired instantaneous output power p^*_o can be derived as

$$P_{\text{in}} = v_{\text{in}} i_{\text{in}} = V_{o,\text{ref}} i_o^* = p_o^*$$

Where Vo ,ref is the reference output voltage and i^*_o is the desired output current.When the constant output voltage is achieved, i^*_o is expressed as

$$i_o^* = \frac{v_{\text{in}} i_{\text{in}}}{V_{o,\text{ref}}} = \frac{V_m I_m}{V_{o,\text{ref}}} \sin^2 \omega t.$$

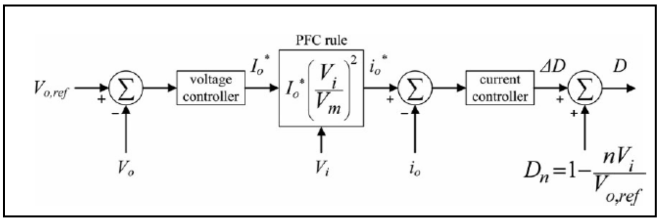

Fig. 8: Control Block Diagram of Proposed Converter

i^*_o is proportional to sin2ωt. Therefore, i^*_o for PFC and power control can be expressed as

$$i_o^* = I_o^* \left(\frac{V_i}{V_m} \right)^2$$

Where, i^*_o is the amplitude of the desired output current . v_i is the input voltage, v_m is the voltage across inductor L2,D is the duty cycle of PWM,ΔD is the change in the duty cycle.

VI. Comparison

S.NO	EXISTING SYSTEM	PROPOSED SYSTEM
1	Open loop control	Closed loop control
2	Low power factor	High power factor
3	Less efficient	More efficient
4	Fast response	Slow response
5	Suitable for fixed load	Suitable for variable load

Table 1:

VII. Results and Conclusion

A. Hardware Output:

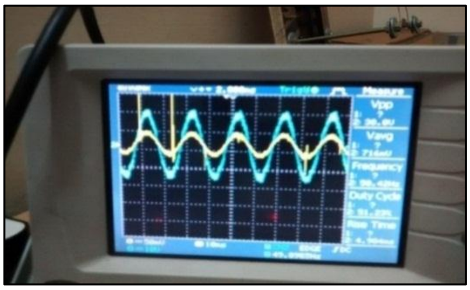

Fig. 9: Hardware Output

Fig.9 shows our proposed system output using zeta converter. The shape of the output is pure sinusoidal.

B. Simulation Output:

1) Existing System:

The existing system from fig.13 is a ZETA converter with an open loop control. The input AC supply is converted into fixed DC by using the bridge rectifier and the filtering capacitor. The MOSFET block is made to work on switch

ON and switch OFF mode by receiving the square wave PWM pulse from the PWM pulse generator. The power factor measurement block measures the power factor in the input AC side. This system was tested by a simple simulation and is shown in Fig. 10.The waveform shows that the voltage and current waveforms are not in phase.

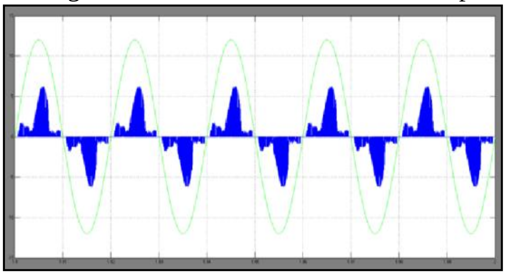

Fig. 10: Input of Existing System

2) Proposed System:

The proposed system is a ZETA converter with a closed loop control shown in fig.14. The input AC supply is converted into fixed DC by using the bridge rectifier and the filtering capacitor. The MOSFET block is made to work on switch ON and switch OFF mode by receiving the PWM pulse from the PWM pulse generator from the closed loop. The closed loop consists of voltage controller which gives error signal and the current controller gives error signal by novel control equation. The current controller error signal is passed through the saturation block which limits error signal range. The voltage controller error signal and the current controller error signal are added to give a change in duty cycle signal. This change in duty cycle signal is limited within range to prevent saturation is done by saturation block. Finally the change in duty cycle is taken by the PWM generator to generate pulse for MOSFET switching operation. This system was tested by a simple simulation and is shown in Fig. 11 . The above figure shows that the voltage and the current waveform are in phase.

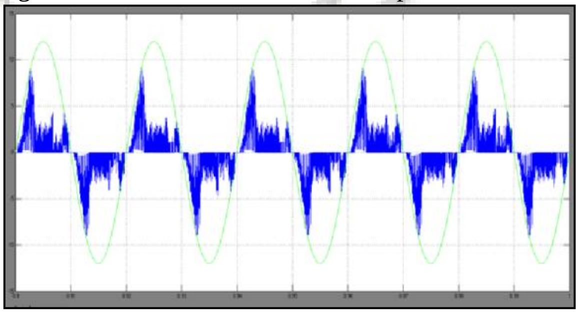

Fig. 11: Input of Proposed System

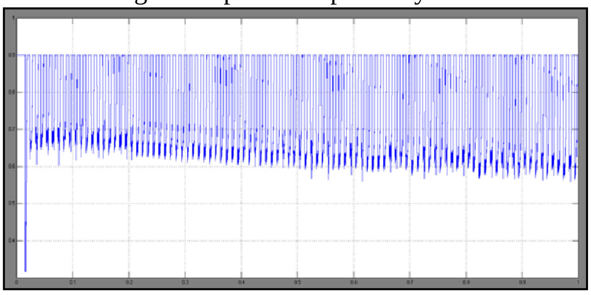

Fig. 12: PWM Gate Pulse for the Proposed System

The fig.12 shows the PWM pulse given to the MOSFET gate.

Annexure -1

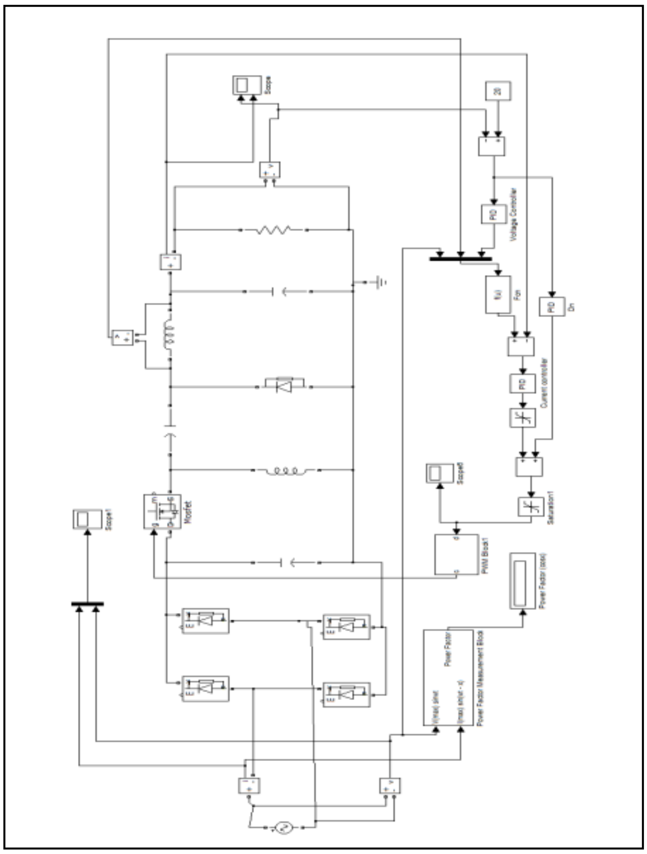

Fig. 13: Simulation Circuit diagram for Existing System

Annexure-2

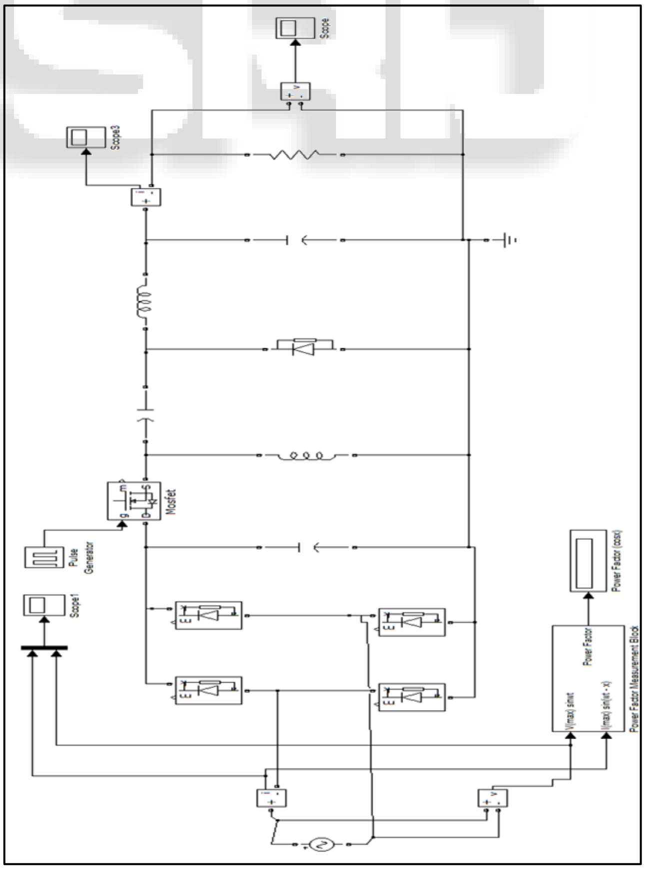

Fig. 14: Simulation Circuit Diagram for Proposed System

VIII. Conclusion

The power factor correction PWM Zeta converter system uses just the microcontroller for implementing the novel control algorithm for closed loop operation. This eliminates any complex circuitry making it less cost. Thus improving the power factor increases the quality of electric supply eliminating the harmonics. This also eliminates the stresses on the switching devices by correcting the peaks. Thus the zeta converter can replace the existing DC converters with more efficient operation and single stage power conversion. The Power Factor Correction PWM Zeta converter is proposed to run the BLDC motor and SMPS with very good power factor correction in the input supply and also increases the efficiency. The future scope of the system will be in industrial manufacturing, heating and ventilation due to its compactness, efficiency and less cost. Finally, the performance of the proposed scheme has been validated on a developed hardware prototype with improved power quality at AC mains.

References

[1] E.Niculescu,M.C.Niculescu,M.Percaru,“Modelling the PWM zeta converter in discontinuous conduction mode”, IEEE journal,2008
[2] Yong-Won Cho, Jung-Min Kwon, Bong-Hwan Kwon,“Single power AC-DC converter with high power factor and high efficiency”, IEEE transactions on power electronics, vol.29, No.9, september 2014.
[3] Jitty Abraham, K.Vasanth,”Design and Simulation of Pulse-Width Modulated ZETA Converter with Power Factor Correction”, International Journal of advanced trends in computer science and engineering, 2013.
[4] Hao Zhang, Yuan Zhang, Xikui Ma, “Distortion Behavior Analysis of General Pulse-Width Modulated Zeta PFC Converter Operating in Continuous Conduction mode”, IEEE transactions on power electronics, vol.27, no.10,October 2012.
[5] Huai Wei, Issa Batarseh, Senior Member, IEEE, Guangyong Zhu, Member, IEEE, and Peter Kornetzky, “A Single-Switch AC–DC Converter with Power Factor Correction”, IEEE Transactions on power electronics, vol.15, no. 3, May 2000.
[6] Pijit Kochcha, Sarawut Sujitjorn, "Isolated Zeta Converter: Principle of Operation and Design in Continuous Conduction Mode", Wseas Transactions on Circuits and Systems , Issue 7, Volume 9,July 2010.
[7] Endo, H. NTT Interdisciplinary Res. Lab., Tokyo, Japan Yamashita, T. ; Sugiura, T.“A high-power-factor buck converter” Power Electronics Specialists Conference, 1992. PESC '92 Record, 23rd Annual IEEE Date of Conference June 29 1992-July 3 1992.
[8] D.C. Martins, “Zeta Converter Operating in Continuous Conduction Mode Using the Unity Power Factor Technique”, in Proceedings of IEE PEVSD’96, 1996, pp.7-11.
[9] F. Wu, S. A. Ljang and Y. M. Chen, “Design Optimization for Asymmetrical ZVS-PWM Zeta Converter”, IEEE Trans. on Aerospace and Electronic Systems vol. 39, no.2, pp. 521-532,April 2003.
[10] C. Sudhakarababu, and M. Veerachary, “Zeta converter for power factor correction and voltage regulation,” IEEE Region 10 Conference, TENCON, vol.4, pp.61-64, 2004.

