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Simulation of AC-DC Converter for High Power Application

S. Ramarajan[1],.R.Samuel Rajesh Babu[2]
Department of EEE, Sathyabama Institute of Science and Technology, India.

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ABSTRACT

This manuscript deals with the simulation of DC - DC Zeta converter for high power drive application with greater efficiency, lesser losses and power factor correction. It involves simpler control circuitry with less external components. The explanation of Fundamental function of Zeta converter is given in this paper. To condense the harmonic content the PI, PID and Fuzzy Logic controller are used. The operation of Zeta converter in open loop, closed loop is obtained. Closed loop system of zeta converter proves better performance over open loop system. Open and closed loop circuits are simulated by using MATLAB simulink. By giving disturbance in closed loop and open loop systems, feat of Zeta converter is compared

Corresponding Author:

S.Ramarajan,
Department of Electrical and Electronics Engineering,
Sathyabama Institute of Science and Technology,
Rajiv Gandhi Salai, OMR road, Chennai, India-600119.
Email: ramarajan122@gmail.com

1. INTRODUCTION

The conventional system of AC-DC translation by a diode rectifier with bulkiness capacitor is not using due to several difficulties, such as high crest current, low power factor, increased electromagnetic interfering, low order harmonics injection into AC supply, line voltage distortion, extra burden on lines, and supplementary losses. Solid-state switch mode rectifier converters have arrived at a established level for enlightening power quality in terms of power-factor improvement (PFI) and reduced total harmonic distortion (THD). The control of output voltage and improving the power factor is major challenge. The basic dc-to-dc converter topologies using Boost converter, Buck-converter and Buck-Boost converter have their inherent boundaries when used for power factor correction beside with voltage regulation purposes.

In the proposed method a comparatively new class of AC to DC converter, and Zeta converter is used for active PFC and voltage regulation having advantages of being normally inaccessible structure, can operate as both step up/down voltage converter and having only one stage power processing for both voltage regulation and PFC. A Zeta converter performs a non-inverting buck-boost function similar to that of a SEPIC. But in application which implies high power, the operation of a converter in discontinuous mode is not attractive because it results in high rms values of the currents causing high levels of stress in the semiconductors. 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.The conventional boost converters are not preferred, because at high voltage duty ratio it causes severe losses in power devices and high voltage stress across the switching devices. The diode reverse recovery problem increases the conduction losses, degrade the efficiency and limit the power level of conventional boost converter. Owing to this scenario integrated boost fly back converter is designed to reduce these problems and to interface with renewable energy system.

2. ZETA CONVERTER

A zeta converter is a fourth order non linear system being that, with regard to energy input, it can seen as buck-boost-buck converter and with regard to the output, it can be seen as boost-buck-boost converter.

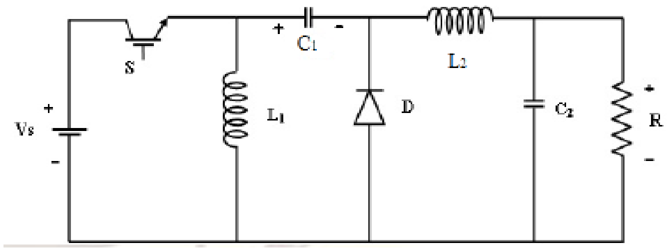

Figure 1. Basic Zeta Converter Circuit

The ideal switch based realization of zeta converter is depicted. A non-isolated zeta converter [2] circuit is shown in the fig.1 above. Although several operating modes are possible for this converter depending on inductance value, load resistance and operating frequency, here only continuous inductor current “iL1” analyzed using the well known state-space averaging method [3]. The analysis uses the following assumptions.
1. Semiconductors switching devices are considered to be ideal.
2. Converter operating in continuous inductor current mode.
3. Line frequency ripple in the dc voltage is neglected.

3. MODES OF OPERATION

Zeta converter exhibits two different modes as follows:

- **Mode1:** The first mode is obtained when the switch is ON (closed) and instantaneously, the diode *D* is OFF. An equivalent circuit of zeta converter is shown in Figure 2. During this period, the current through the inductor *L*1 and *L*2 are drawn from the voltage source Vs. This mode is the **charging** mode.
- **Mode2:** The second mode of operation starts when the switch is OFF and the diode *D* is ON position, the equivalent circuit shown in Figure 3. This stage or mode of operation is known as the **discharging** mode since all the energy stored in **L2** is now transferred to the load **R.**

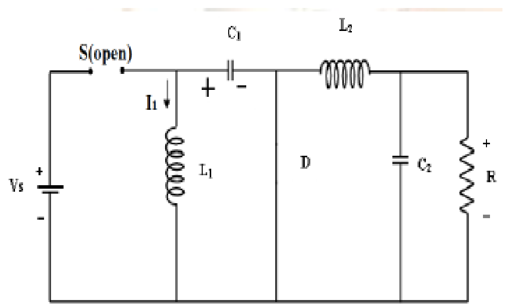

Figure 2. Equivalent Circuit of Converter (switch ON)

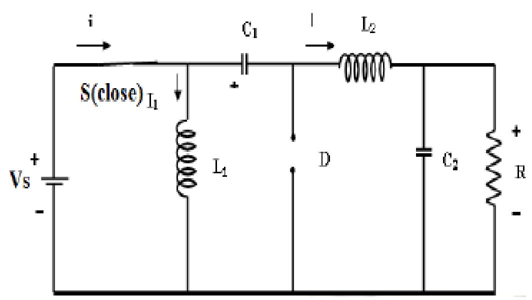

Figure 3. Equivalent Circuit of Converter (switch ON)

4. SIMULATION MODELS AND RESULTS

The zeta converter is driven by a single switch. The zeta converter is simulated in both open and closed loop, without and with disturbance using MATLAB simulink and the results are taken. The output parameters are displayed by the Scope.

The experimental circuits and their results of ZETA converter in open loop and closed loop systems are given below.

4.1. Open Loop Circuit of Zeta Converter with C Filters without Disturbance:

The simulated diagram of open loop zeta converter (with C filter) with R load is shown in Figure 4. And its output parameters are measured.

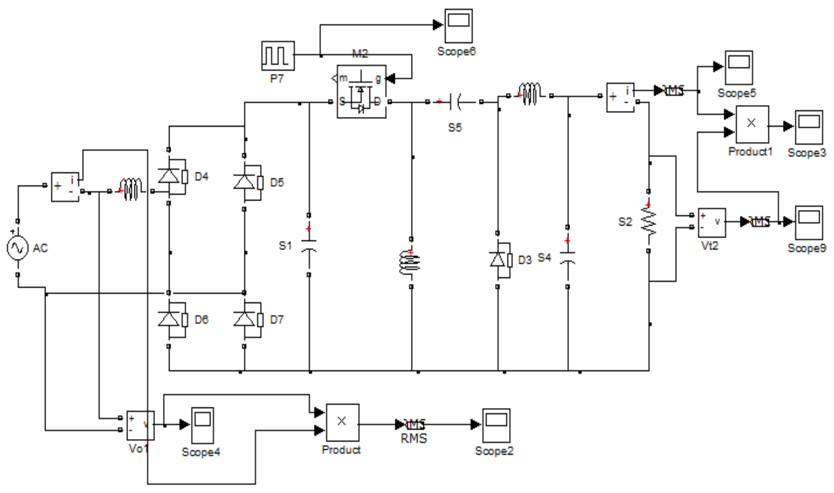

Figure 4. Circuit Diagram for Zeta Converter with C Filter

The Figure 5 shows the input voltage of zeta converter (with C filters) with R load. The Figure 6 shows the input power and Figure 7 shows the switching pulse of zeta converter with R load. And also Figure 8, 9 and 10 shows the output voltage, output ripple voltage, output current respectively.

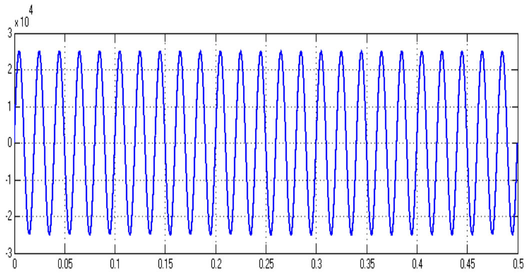

Figure 5. Input Voltage

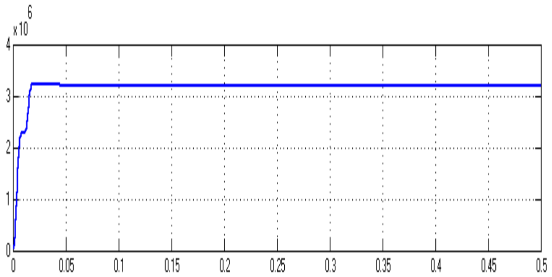

Figure 6. Input Power

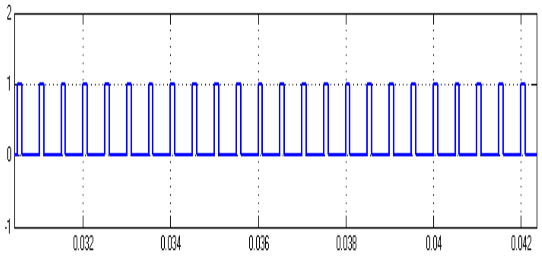

Figure 7. Switching Pulse For Zeta Converter

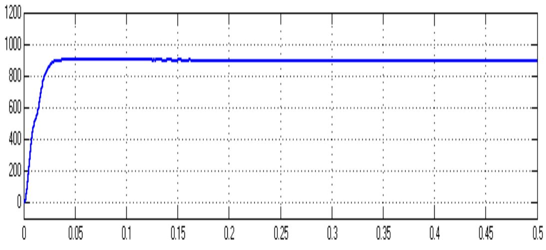

Figure 8. Output Voltage

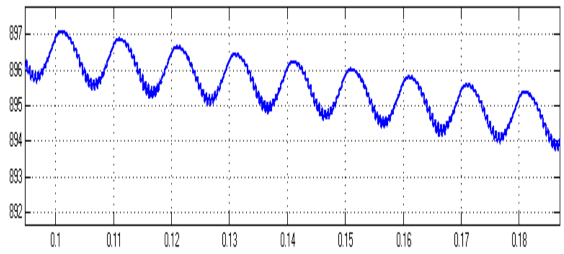

Figure 9. Output Ripple Voltage

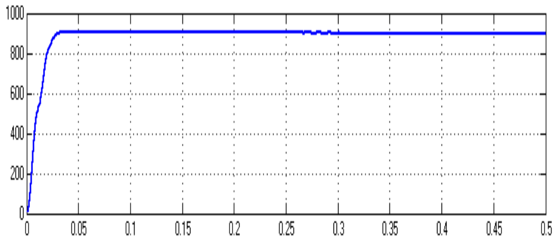

Figure 10. Output Current

4.2. Open Loop Circuit of Zeta Converter with Π Filters Without Disturbance.

The simulated diagram of open loop zeta converter (with π filters) with R load is shown in Figure 11. And its output parameters are measured.

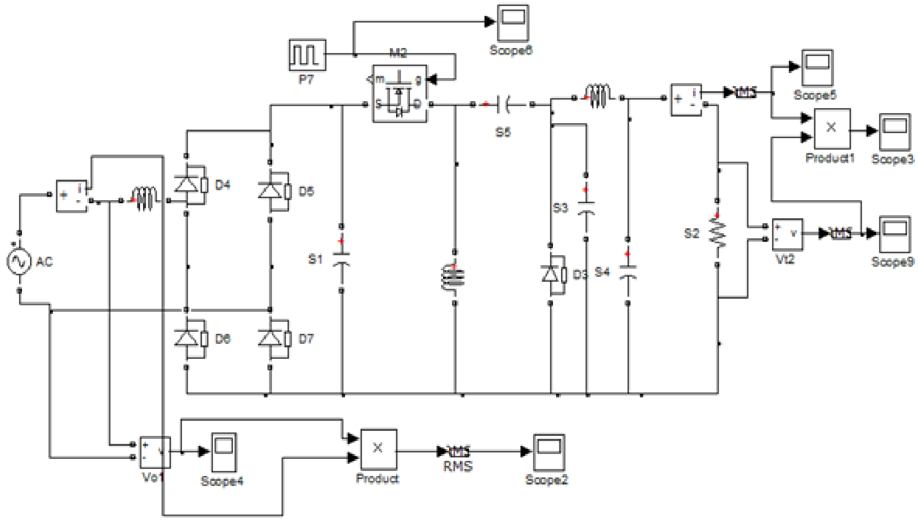

Figure 11. Circuit Diagram for Zeta Converter with Π Filter

The Figure 12 shows the input voltage of zeta converter (with π filters) with R load. The Figure 13 shows the input power and Figure 14 shows the switching pulse of zeta converter with R load. And also Figure 15, 16 and 17 shows the output voltage, output ripple voltage and output current respectively.

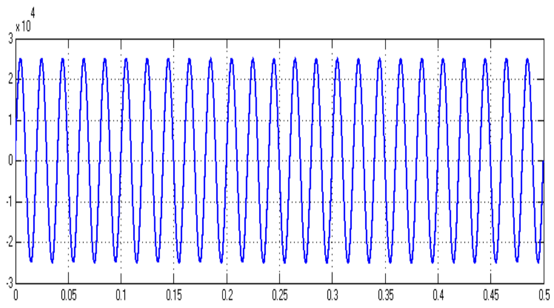

Figure 12. Input Voltage

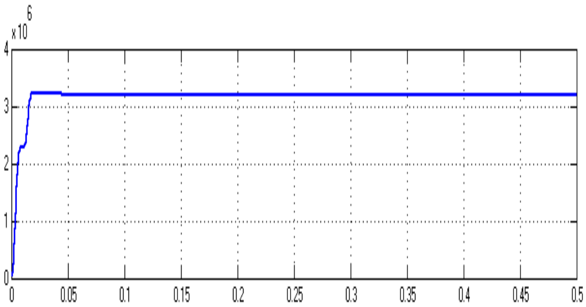

Figure 13. Input Power

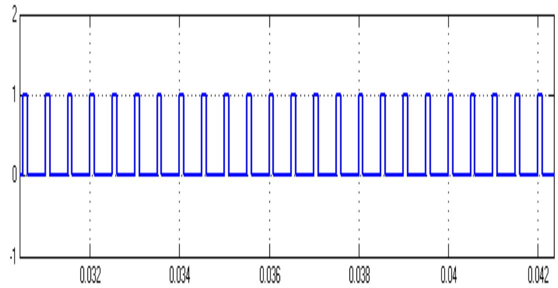

Figure 14. Switching Pulse For Zeta Converter

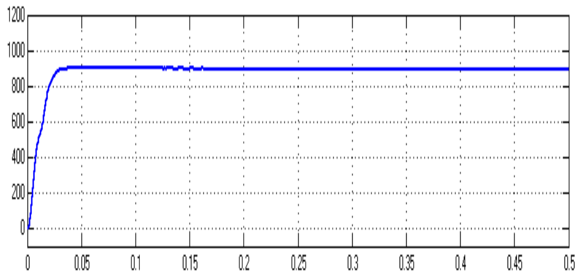

Figure 15. Output Voltage

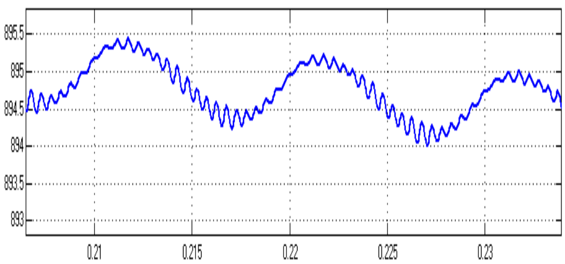

Figure 16. Output Ripple Voltage

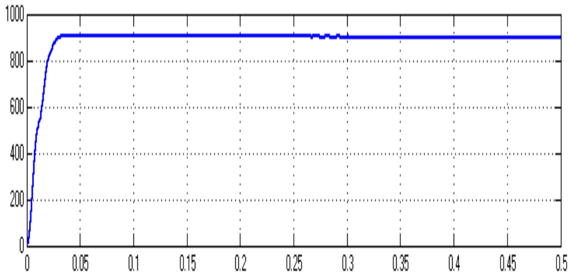

Figure 17. Output Current

Table 1. Comparison of output voltage ripple

Zeta Converter	Voltage Ripple
C-filter	1.1V
π-filter	0.6V

Table 2. Comparison of output voltage rippleWith π-filter

Zeta Converter	Voltage Ripple
LCL	0.6V
LLC	1.2V
CCL	0.9V
CLC	1.8V
LCC	1.4V
CLL	1.6V

From the above results, the output voltage ripple is very less in π filter. And also from π filter combinations LCL filter is giving very less voltage ripple.

4.3. Closed Loop Circuit with PI Controller.

The simulated diagram of closed loop zeta converter (with π filters) with R load is shown in Figure 18. Here the PI controller is used. And its output parameters are measured.

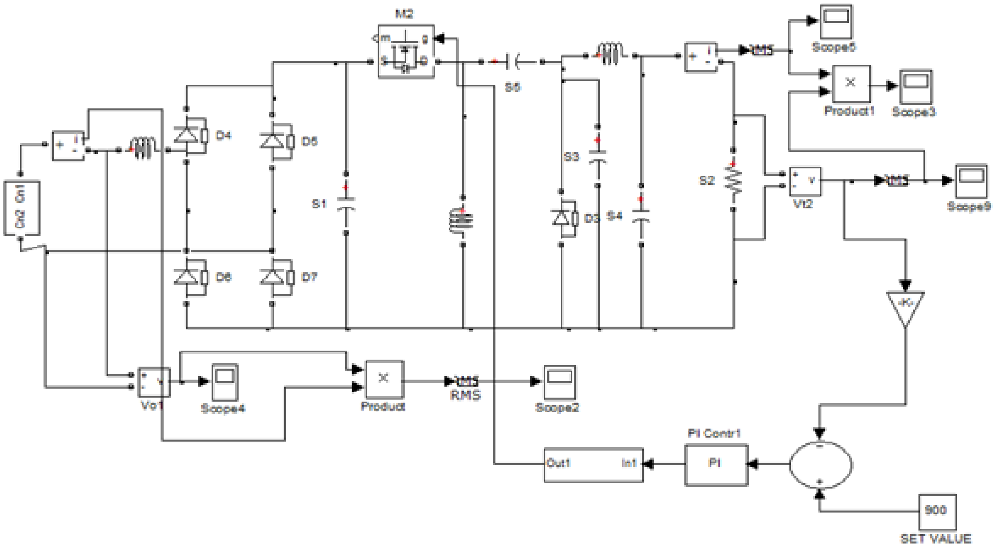

Figure 18. Closed Loop with PI Controller

The Figure 19 shows the input voltage of zeta converter (with π filters) with R load. The Figure 20 shows the output voltage. And also Figure 21 shows the output current.

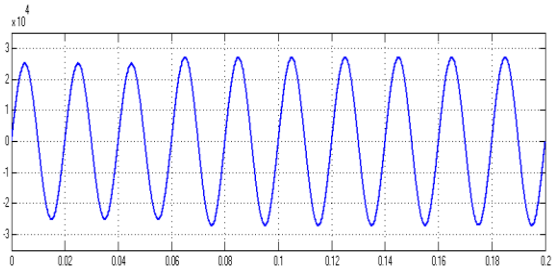

Figure 19. Input Voltage

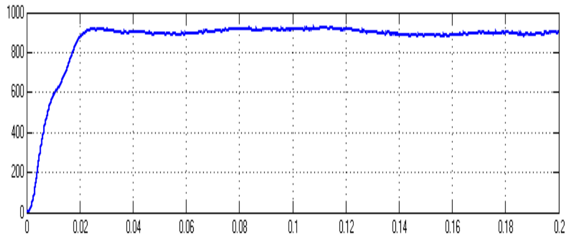

Figure 20. Output Voltage

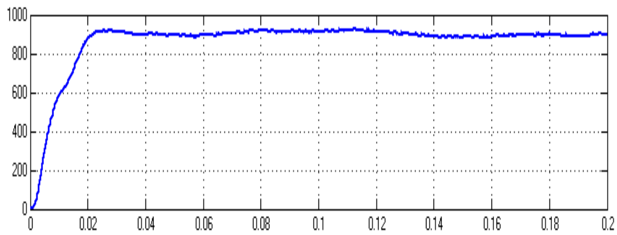

Figure 21. Output Current

4.4. Closed loop circuit with PID controller.

The simulated diagram of closed loop zeta converter (with π filters) with R load is shown in Figure 22. Here the PID controller is used. And its output parameters are measured.

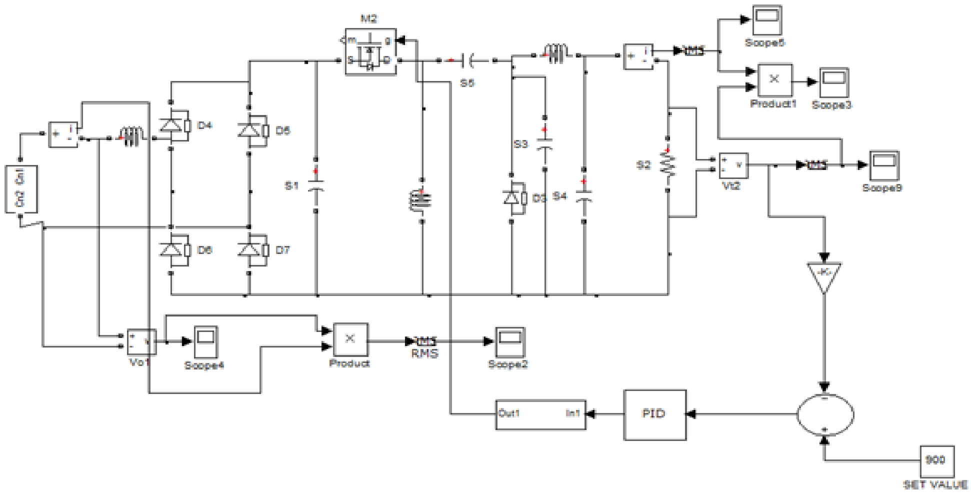

Figure 22. Closed Loop PID Controller

The Figure 23 shows the output current of zeta converter (with π filters) with R load. The Figure 24 shows the output voltage of the closed loop with PID controller.

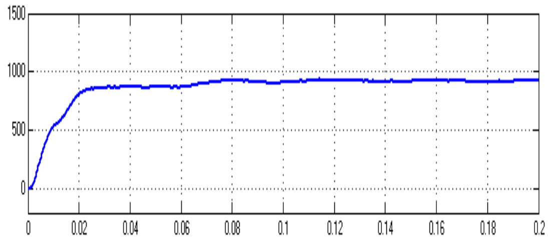

Figure 23. Output current

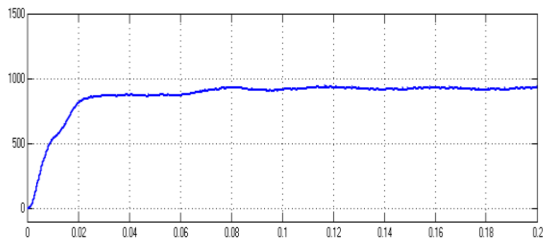

Figure 24. Output voltage

4.5. Closed loop circuit with Fuzzy Logic controller.

The simulated diagram of closed loop zeta converter (with π filters) with R load is shown in Figure 25. Here the fuzzy logic controller is used. And its output parameters are measured.

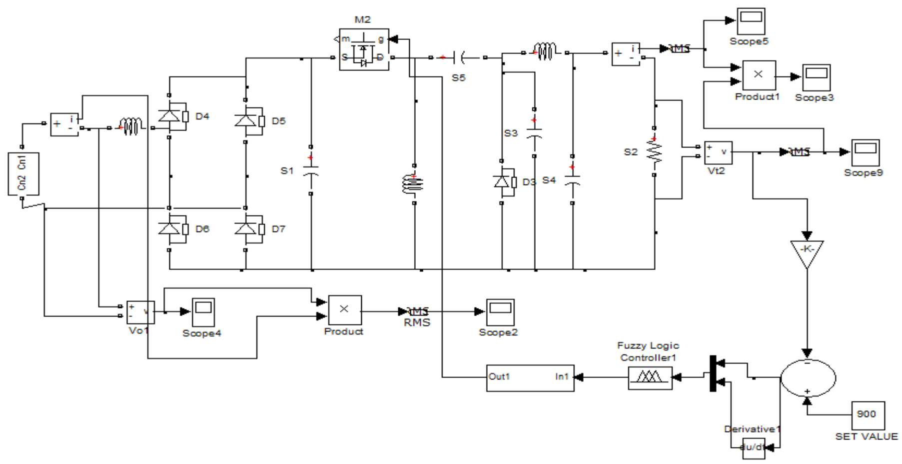

Figure 25. Closed Loop with FLC

The Figure 26 shows the output voltage of zeta converter (with π filters) with R load. The Figure 27 shows the output current of closed loop with fuzzy logic controller.

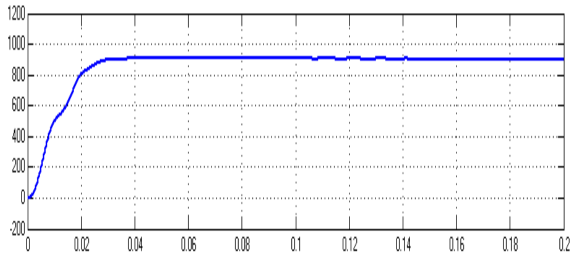

Figure 26. Output voltage

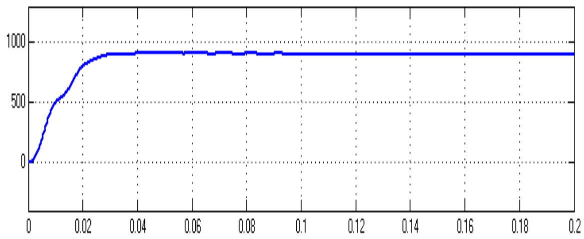

Figure 27. Output current

Table 3. Comparison of Time Domain Parameters

Controller	Tr	Ts	Tp	Ess
PI	0.07	0.12	0.08	0.3
PID	0.06	0.09	0.07	0.2
FUZZY	0.03	0.05	0.04	0.08

From the above results, the Fuzzy Logic Controller is best controller. Because in this controller the rise, settling time and peak overshoot is very less. So Fuzzy logic controller is very best controller for zeta converter.

5. EXPERIMENTAL RESULTS

The Experimental setup of zeta converter is shown in Figure 28. In this AC is converted as DC supply and that DC supply is given as an input of the zeta converter. Here the fuzzy logic controller is used as a controller circuit for zeta converter. The output of zeta converter is given to the Resistive Load.

Figure 28. Experimental Setup of Zeta Converter.

6. CONCLUSION

The Mathematical analysis of ZETA converter is carried out for design values of the capacitor and inductor. A simple power electronic controller with load has been simulated using ZETA converter. The subsystems of overall scheme such as controller model, ZETA converter model have been built and tested individually before integrating to the overall system. The simulation studies of the proposed scheme of PI, PID and Fuzzy controllers carried out and the results are furnished. The values of parameters used for simulation are listed.

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BIOGRAPHIES OF AUTHORS

Mr.S.Ramarajan has completed B.E from Anna university in 2008. He obtained M.E degree in the field of Power Electronic & Industrial Drives from Sathyabama University in 2012. Presently he is working as Assistant Professor in Jeppiaar Engineering College, Chennai and doing his research in power electronics. His areas of interest are power electronics, electrical machines speed control and intelligent controller.

Dr. R. Samuel Rajesh Babu has obtained his B.E Degree from Madras University in 2003. He obtained his M.E degree from Anna University in 2005. He obtained his Ph.D degree from Sathyabama University in 2013. Presently he is a Associate Professor in Sathyabama University. His areas of interest are Power Electronics and Digital Protection.