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Modified Zeta Converter with Power Factor Correction for Arc Welding

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ABSTRACT: This paper proposed a modified zeta converter having two switches and two clamping diodes on the primary side of high frequency transformer for Arc Welding Power Supply(AWPS) application. The proposed converter is operated in discontinuous inductor current mode and results in reduced switch stress and also able to maintain constant output voltage. The main advantage of proposed AWPS is its simple to control, since only one gating signal is used to drive both the switches. Using Fuzzy Logic Controller, the proposed converter offers better efficiency, lower total harmonic distortion(THD) and power factor correction at the utility. The simulation is carried out by MATLAB/Simulink environment.

KEYWORDS: Zeta converter, Power factor correction (PFC), power quality (PQ), welding power supply, Fuzzy controller.

I.INTRODUCTION

Switched DC-DC converters aid in increasing the voltage from a low battery voltage thereby facilitating in accomplishing a regulated DC output voltage which would rather require multiple battery sources. From the past AC-DC conversion, normally employs a diode bridge rectifier with filter capacitor. Such rectifier injects low order harmonics into the AC lines to which they are connected. This leads to low power factor, high current stress and line voltage distortion. Various converters like boost, buck, buck-boost, cuk, sepic and zeta were employed in power factor correction in both continuous and discontinuous mode.

Though zeta converter is similar to that of a buck-boost converter, it has an advantage of non-inverted output. It has a wider range of duty ratio than any other converter. The converter exhibits improved power factor, low input current distortion, low output current ripple and wide output-power range. A boost converter is a DC-DC converter in which output voltage is greater than input voltage, while stepping down a current. As the control input appears in both voltage and current equation, the controlling of boost converter is difficult. Therefore, Zeta converter is a fourth order converter which has natural isolation, providing protection to the load circuit from the source, during abnormal conditions at the source side. The goal of developing AC-DC converters with Power Factor Correction (PFC) feature in a single power processing stage.

Several single-stage isolated PFC topologies are reported in the literature that possess a simple power circuit with easy control schemes compared with two-stage PFC converters. It results in the reduction in the cost and complexity of upcoming PFC converters. Among them, an isolated zeta converter offers reduced inrush current and excellent overload current protection. However, the conventional isolated zeta ac–dc converter suffers from a major drawback of high voltage stress across the switch. This, in turn, increases the switching losses . Inorder to improve the power quality at the supply by reducing the total harmonic distortion factor and increasing power factor to unity, this paper deals with the analysis, design, and development of the two-switch modified zeta converter operating in the DICM, with high-frequency isolation, regulated output voltage, and improved PQ.

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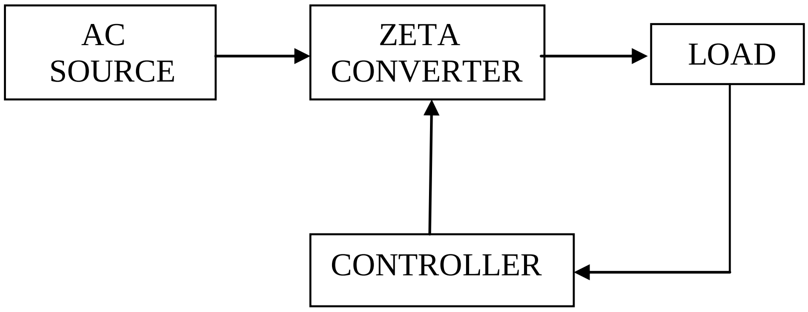

Fig. 1 Block Diagram.

II.OPERATING PRINCIPLE OF PROPOSED MODIFIED ZETA CONVERTER

Fig. 2 shows the configuration of the modified isolated zeta converter for a single-phase AWPS. It comprises of single phase supply followed by diode bridge rectifier, LC filter ,two switches, two diodes, HFT, two capacitors C_1 and C_2, two inductors L_1 and L_2 an d a standing resistive load R.

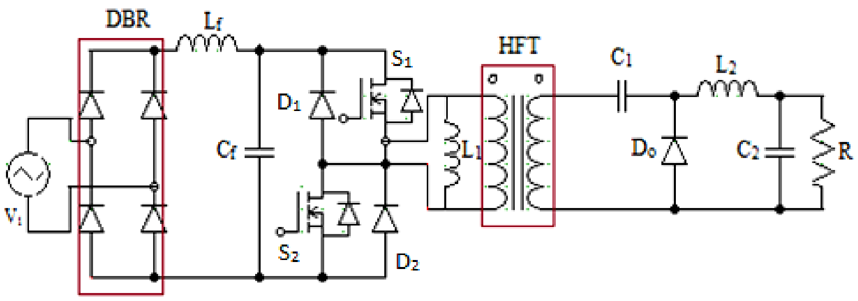

Fig. 2 Circuit diagram for proposed modified zeta converter.

The operation of modified zeta converter is designed in Discontinuous Inductor Current Mode (DICM) and the circuit operation can be defined by three modes of operation are shown in Fig. 3, Fig. 4 and Fig. 5 respectively.

a) Mode 1

In this mode, both switches S_1 and S_2 are turned ON and the diode D_1 and D_2 are remain OFF. Inductors L_1 and L_2 are charged from the source and the inductor current i_{L1} and i_{L2} are increases linearly. Diode D_o is reverse biased and also discharging of C_1 and charging of C_2 take place.

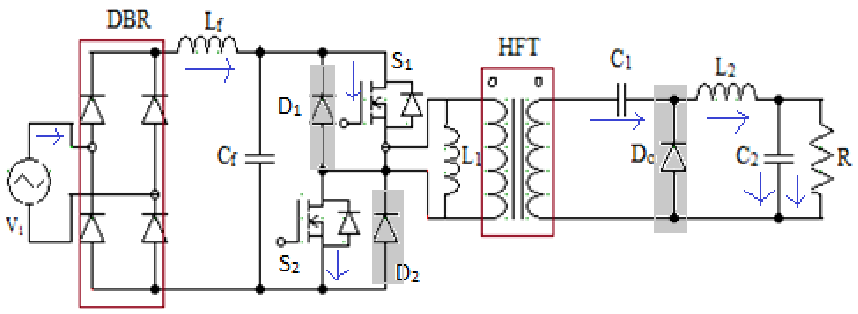

Fig. 3 Mode 1 operation of modified zeta converter.

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b) Mode 2

In this mode, both switches are turned OFF and the diode D_1 and D_2 are forward biased. During this interval, previously charged inductor L_1 starts to discharge. So stored energy in L_1 and L_2 are discharged through capacitors C_1 and C_2. Therefore, the inductor currents i_{L1} and i_{L2} decreases gradually. During this time interval, the current through the diodes D_o decreases, until it becomes zero.

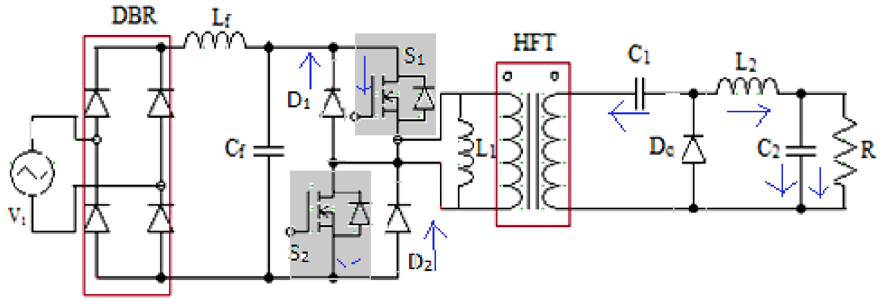

Fig. 4 Mode 2 operation of modified zeta converter.

c) Mode 3

when the absolute values of currents in L_1 and L_2 become equal to each other, thereby reverse biasing the diode D_o again. Thus, the magnetizing inductor L_1 enters DICM. The capacitor C_1 and C_2 discharges during this period to release their stored energy. This stage continues until both the switches start conducting.

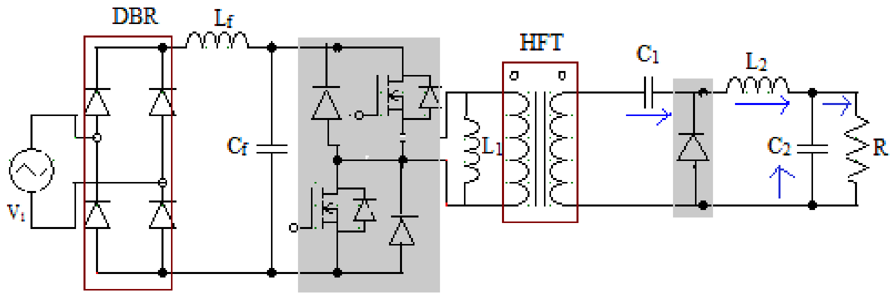

Fig. 5 Mode 3 operation of modified zeta converter.

The associated waveforms for this converter over one switching period are presented in Fig. 6.

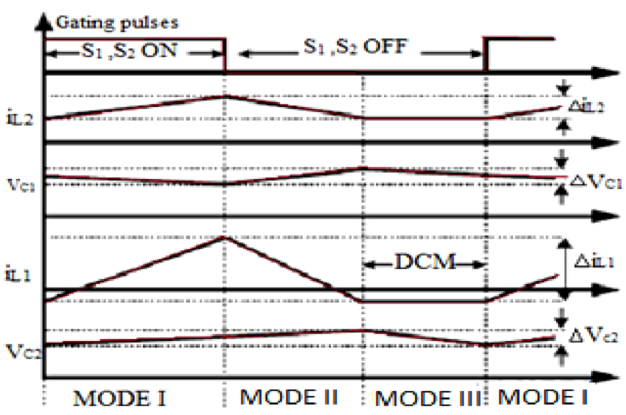

Fig. 6 Waveform during one switching period.

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III. DESIGN OF THE PROPOSED MODIFIED ZETA CONVERTER BASED AWPS

The design of the proposed zeta converter-based AWPS is given in this section. The parameters of the proposed converter are designed, such that it operates in DICM to attain inherent PFC at ac mains.

The average input voltage V_d , after rectification of input ac voltage V_1, is given by

$$V_d = \frac{2V_1\sqrt{2}}{\pi} \tag{1}$$

The value of intermediate inductor (L_1) and output inductor (L_2) are given as,

$$L_{1\,mim} = \frac{n^2 R(1-D)^2}{2D\, f_s} \tag{2}$$

Therefore DICM operation , $L_1 << L_{1\ min}$.

$$L_2 > \frac{V_0(1-D)}{f_s \Delta i_{L2}} \tag{3}$$

The value of filter capacitor (C_f) and filter inductor (L_f) are given as,

$$C_{f\,max} = \frac{I_{1m}}{V_{1m}} \tan\theta \tag{4}$$

Therefore , $C_f << C_{f\ max}$.

$$L_f = \frac{1}{4\pi^2 f_c^2 C_f} - 0.05\left(\frac{1}{\omega}\right)\left(\frac{V_1^2}{P_o}\right) \tag{5}$$

The value of intermediate capacitor (C_1) and output capacitor (C_2) are given as,

$$C_1 = \frac{D V_0}{f_s R_0 \Delta V_{C1}} \tag{6}$$

$$C_2 \geq \frac{I_0}{2\omega \Delta V_0} \tag{7}$$

The design specifications of the proposed zeta converter are summarized in Table I.

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TABLE I. SPECIFICATIONS FOR THE PROPOSED MODIFIED ZETA CONVERTER

ATTRIBUTES	PARAMERTERS
Output Power, P_0	760W
Supply Voltage, v_s@50Hz	220V
Output DC Voltage, V_0	19V
Output DC Current, I_0	40A
Switching frequency, f_s	20KHz
Intermediate Capacitor, C_1	70μF
Magnetizing Inductor, L_1	180μH
Turns Ratio, N_1/N_2	2.75
Output Inductor, L_2	250μH
Output Capacitor, C_2	36mF
Input Filter Inductor, L_f	4mH
Input Filter Capacitor, C_f	440nF

IV. CONTROLLER TECHNIQUE

A) Introduction to Fuzzy Logic Controller

Fuzzy set theory is widely used in the control area with some applications to dc-to-dc converter system. A simple fuzzy logic controller is made up by a group of rules based on the human knowledge regarding the system behaviour. Matlab/Simulink simulation model is built to study the performance of proposed controllers and dynamic behaviour of dc-to-dc converter. The fuzzy logic controller has the ability to improve the robustness of dc-to-dc converters. A Fuzzy Logic controller forms an integral part of controller which processes the error resulting from the comparison of the voltage reference and sensed voltage at DC link. The resultant voltage error is compared with a saw-tooth carrier wave of fixed frequency (*fs*) for generating the PWM pulses for controlling switch of PFC converter.

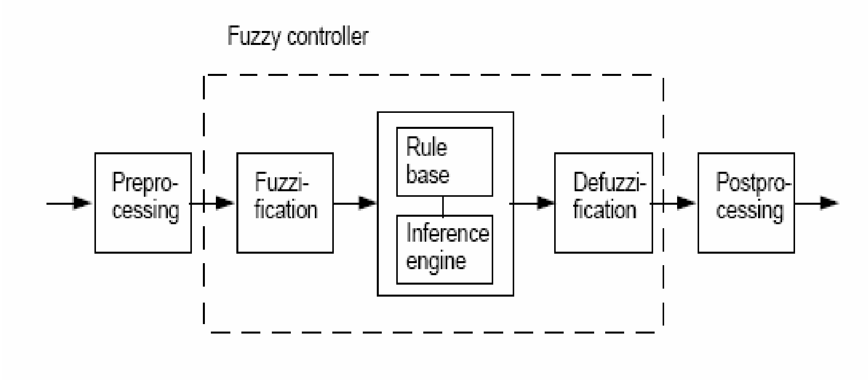

Fig. 7 Structure of Fuzzy Logic Controller.

B) Fuzzy logic Rules

The error and change in error values are compared to constuct the rules for the Fuzzy logic controller. The rules for the fuzzy logic controller are listed in the Table II.

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TABLE II. RULES FOR FUZZY LOGIC CONTROLLER

INPUT2 / INPUT1	NB	NS	ZE	PS	PB
NB	NB	NB	NB	NS	ZE
NS	NB	NB	NS	ZE	PS
ZE	NB	NS	ZE	PS	PB
PS	NS	ZE	PB	PB	PB
PB	ZE	PS	PB	PB	PB

V. SIMULATION STUDIES AND RESULTS

The performance of proposed zeta converter is analyzed. The output voltage and output current can be regulated and controlled by controller.

A) Simulink model of open loop converter
The open loop simulink model of the proposed converter has been designed.

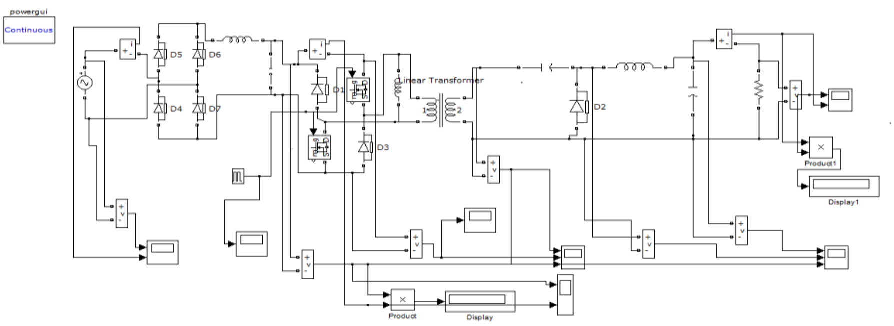

Fig. 8 Open loop control of modified zeta converter.

Output voltage and output current of modified zeta converter in open loop configuration is shown in Fig. 9.

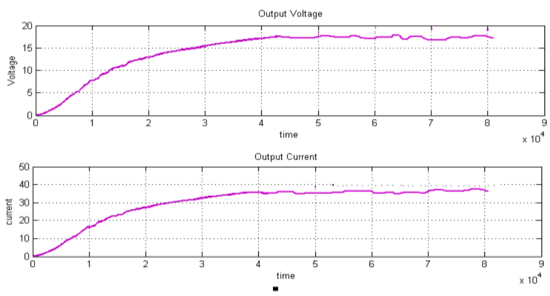

Fig. 9 Simulation output voltage and current of Modified Zeta Converter in open loop control.

B) Simulink model of closed loop converter with PI controller
The closed loop PI controller simulink model of the proposed converter has been designed.

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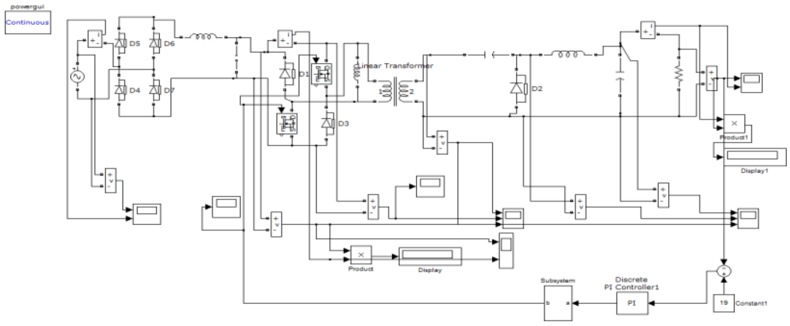

Fig. 10 Closed loop control of modified zeta converter with PI controller

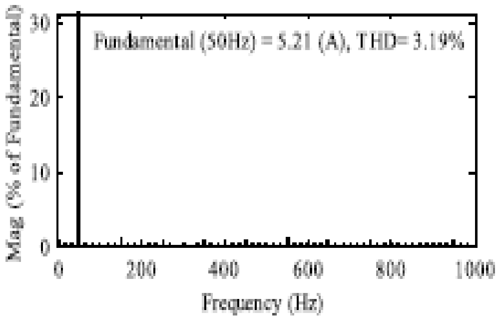

Fig. 11 Harmonic spectrum of input current waveform.

Due to the presence of PI controlled zeta converter in AWPS, the total harmonic distortion has been reduced to 3.19% which is shown in the Fig.11.

C) Simulink model of closed loop converter with fuzzy logic controller

The closed loop fuzzy logic controller simulink model of the proposed converter has been designed.

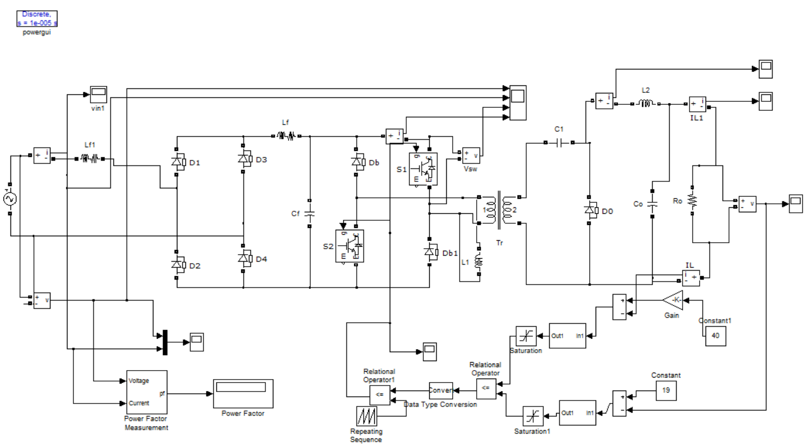

Fig .12 Closed loop control of modified zeta converter with FUZZY Controller.

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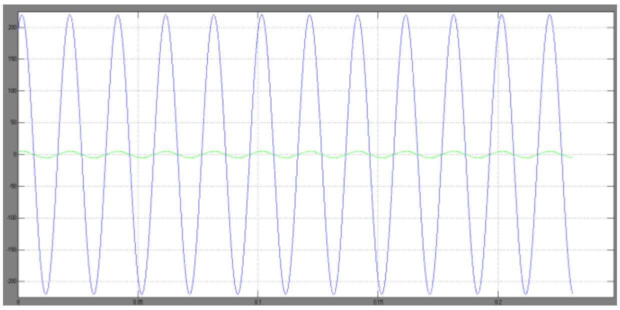

Fig. 13 Input voltage and current waveform.

Output voltage and output current of modified zeta converter in closed loop fuzzy logic configuration is shown in Fig. 14.

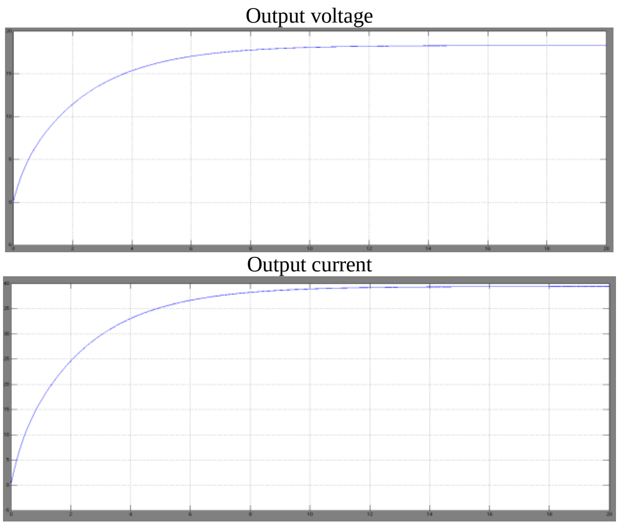

Fig. 14 Simulation output voltage and current of Modified Zeta Converter in closed loop fuzzy controller.

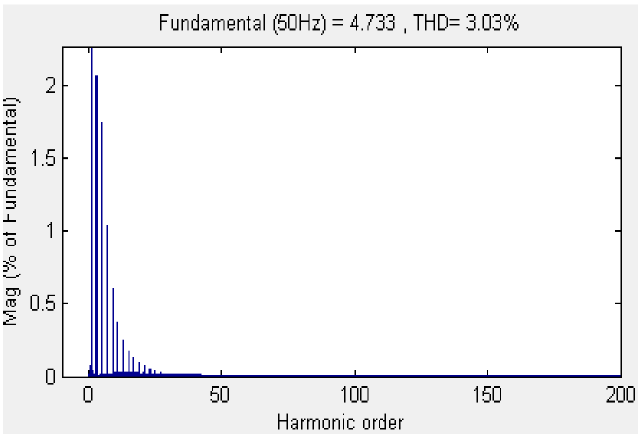

Fig. 15 Harmonic spectrum of input current waveform.

And by using Fuzzy controlled zeta converter the power quality is again improved by reducing the THD value to 3.03% (shown in Fig.15).

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VI.INFERENCE

From simulation results, the output voltage, current and THD are tabulated as below:

TABLE III. OUTPUT VOLTAGE AND OUTPUT CURRENT

Attributes	Open Loop System	Closed Loop System(FUZZY)
Output Voltage	18.9V	19.4V
Output Current	39.8A	40.8A
THD	3.19%	3.03%

VII.CONCLUSION AND FUTURE SCOPE

In this project, the proposed converter is to achieved the power factor correction at the utility, lower total harmonic distortion and also reduced voltage stress across the devices, it posses high reliability. Closed loop performance of PFC converters with fuzzy control strategy have been studied and verified through MATLAB simulation.

As a future expansion, we will be going for a hardware implementation of the work.

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