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Research paper

Implementation of a low cost ac-dc converter for high and low power applications

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Abstract

This paper proposes an ac-dc converter that gives multiple outputs capable of feeding both high and low power applications. The input ac supply is converted to dc by a diode bridge rectifier, filtered and fed to a modified multiport converter (MPC). This paper focuses on the design of the modified multiport converter that has a cascaded combination of zeta and a buck converter. This is designed as a single input and multiple output converter (SIMO) structure which can operate two loads, one with a high power and other with a low power application, depending on the time instant. The need for opting a multiport converter, reduces the number of switches utilized, thereby reducing the switching losses in the circuit. The zeta in the MPC boosts the input voltage and the buck converter reduces the input voltage and is accordingly fed to the need of the load. The design of the components have been analysed through steady state. MATLAB Simulink has been used to simulate the converter circuit and the varied outputs of the zeta and buck modes are compared. A hardware prototype of the ac-dc converter has been implemented and their results have been shown.

Keywords: *Multiport Converter (MPC); Single Input Multiple Output (SIMO); Zeta Converter; Buck Converter; High Frequency Isolation Transformer.*

1. Introduction

With the available ac supply, many new ac to dc converters are being designed to utilize it for dc loads. The advent of new topologies for ac to dc conversion has solved many issues related with switching stress, losses and efficiency. The rectifier converts ac supply to dc, which is then filtered and fed to a modified multiport converter (MPC).This MPC has a cascaded combination of zeta and a buck converter, that supplies dc load of two different power ratings. Power factor correction is done using zero voltage switching, in an isolated AC-DC converter [1] [5].Current injection method is employed to remove the ripples in tha ac supply. The output voltage ripple helps to generate these current injection pulses, in rectangular form [2]. An ac–dc converter, capable of applying it for aircraft system has been designed using 18 pulse converter [3]. Active power filter helps in compensating harmonics in the converter [4]. This requires 12 pulse for its conversion. In most of these cases, the circuit employs more number of switches.
This paper [6] proposes a zeta and a buck boost converter, resulting in higher switching losses, because of more number of switches. Multiport converters employing renewable energy sources are converters with low cost [7] [8]. An adaptive active capacitor converter, stabilizes the cascaded system and detects the bus voltage, employed in high voltage applications[9].[10] Proposes a resonant converter with dual output by adding an auxiliary switch in the circuit.,proving higher efficiency, with more voltage stress. A double ended output structure with buck,boost and inverted output is constructed in [11], [12], resulting in stress in inductor. Smooth control was impossible.

2. Proposed modified multiport converter

The block diagram shows the conversion of ac to dc by using a multiport converter.
The ac input is fed to a diode bridge rectifier and filtered using an LC filter. The filtered output is fed to a modified multiport converter. The multiport converter consists of a zeta and a buck converter that is sequentially controlled to give multiple outputs.

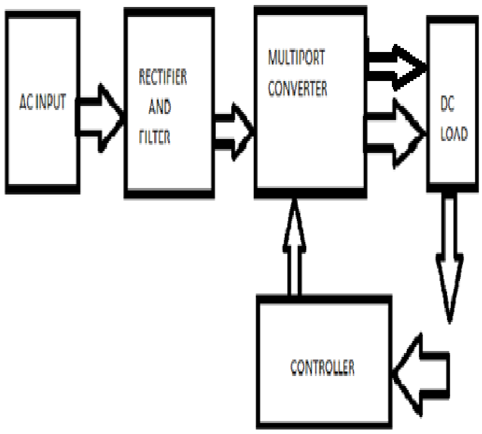

Fig. 1: Block Diagram of the Ac-Dc Converter.

Thus the modified multiport converter is designed as a single input multiple output (SIMO) structure. The outputs obtained from the multiport converter are of different power levels, one with a low power and the other with a high power. This helps in applying a single ac-dc converter to feed two different dc loads.

The ac to dc conversion is carried out using a diode bridge rectifier. The pulsating dc with harmonics are filtered out using LC filter, L_f and C_f. The modified converter is developed using a two switch zeta converter and a buck converter, using an isolated high frequency transformer (HFT).The paper focuses on designing of the modified multiport structure. The diodes D_1 and D_2 are the clamping diodes. The two switches are made to operate in discontinuous conduction mode (DCM) ie the switches are turned on such that, the inductor current goes discontinuous, hence this in turn improves the quality of power.

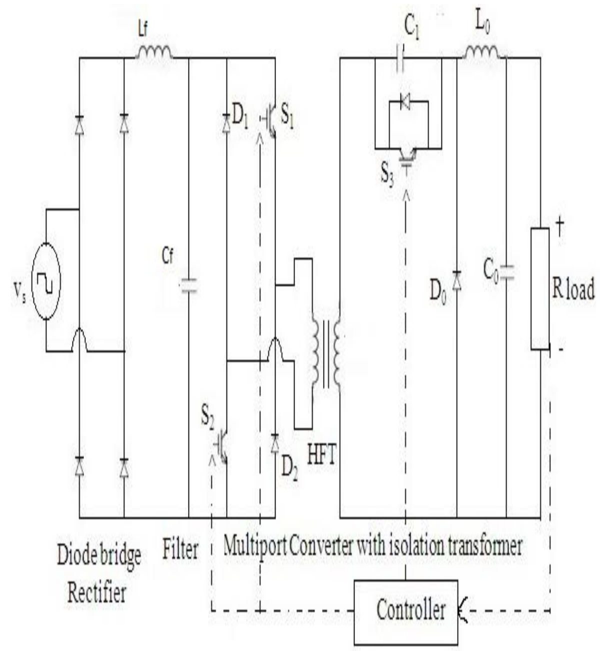

Fig. 2: Circuit Diagram of the Proposed Ac-Dc Converter.

For a wide range of operating power, discontinuous mode of operation is more suitable. Using a suitable controller, the switches S1 and S2 are alternately turned on to suitably operate in zeta mode and in buck mode. The zeta converter probably acts as a buck-boost converter and gives a larger output voltage, than the input voltage and the buck converter reduces the input voltage fed to multiport converter.

2.1. Modes of operation

Three operating modes of the proposed multiport converter.S_1, S_2, S_3 are ideal switches and the supply voltage is constant. f_s =15 kHz, the switching frequency and f=50 Hz, the line frequency.

Mode-I: During this interval, both switches $S_1$and S_2 are turned on and D_1, D2 are turned off. The transformer inductance, Lm increases magnetically. Hence the current in Lo also increases linearly. S_3 is not turned off and diode Do is reversed biased now. C_1 discharges through the load R.

Mode-II: During this mode, both the switches S_1 and S_2, are turned off by the controller and and the diodes D_1 and D_2 now conducts. The magnetizing energy in the isolation transformer is fed to capacitor C_o. Now this forces diode D_o to forward bias and hence the total voltage across the load increases now. S_3 remains in turned off condition only. The current through the inductor current iL_o, gradually reduces and falls down to zero, since the zeta is now being operated in discontinuous mode.

Mode-III: In this mode, both the inductors will have the same magnetising energy, at a particular instant and reverse biases the output diode, D_o. iL_o now increases and holds a maximum value now. C_o is now holding a larger value that is applied across the output load. Thus by operating the converter in discontinuous zeta mode, a larger output voltage is obtained, thus applicable for high power applications.

Mode-IV: In this mode S_3 is operated with D_1 and D_2 on. The capacitor is in discharge mode. Hence the load current now flows through S_3, L_o and to the load. The output voltage now decreases, operating in buck mode. Thus the converter is now acting as a buck converter.

The operation of the multiport converter has been briefed in detail. The output of the converter has varied power capabilities, depending on the mode of operation of the ac-dc converter.

3. Design of the converter

Using volt-sec balance topology, the values of the components in the converter were designed. By applying proper gating signals to the switches, the converter is operated both in zeta mode and buck mode. The gate pulses needed for triggering the switches in the converter are generated by PWM technique. The components were designed for a duty cycle ratio, D of 0.2.

$$C_1 = \frac{DVo}{F_S \Delta VC_1} \quad (1)$$

$$C_o \geq \frac{I_o}{2\Delta V_o} \quad (2)$$

$$L_0 > \frac{V_o(1-D)}{2\Delta iL_o} \quad (3)$$

$$C_{fmax} = \frac{iL0 \tan\theta}{V_{sm}} \quad (4)$$

$$C_f >>> C_{fmax} \quad (5)$$

The magnetizing inductance can be calculated using the following formulae:

$$L_{mmin} = \frac{n^2 R_0}{2Df_s} \quad (6)$$

Magnetizing inductance should be lesser than its minimum value:

$$L_m <<< L_{mmin} \quad (7)$$

$$L_{Total} = L_f + 2L_s \frac{1}{4\pi^2 f_c^2 C_f} \quad (8)$$

4. Simulation of the ac-dc converter

The ac-dc converter has been simulated in MATLAB Simulink environment. The rectified and filtered output is fed to the multiport converter and operated in zeta discontinuous mode. In fig 3, an output voltage of 13V, 28A and 364W output power was obtained, for the simulated circuit. This output could be used for lighting applications.

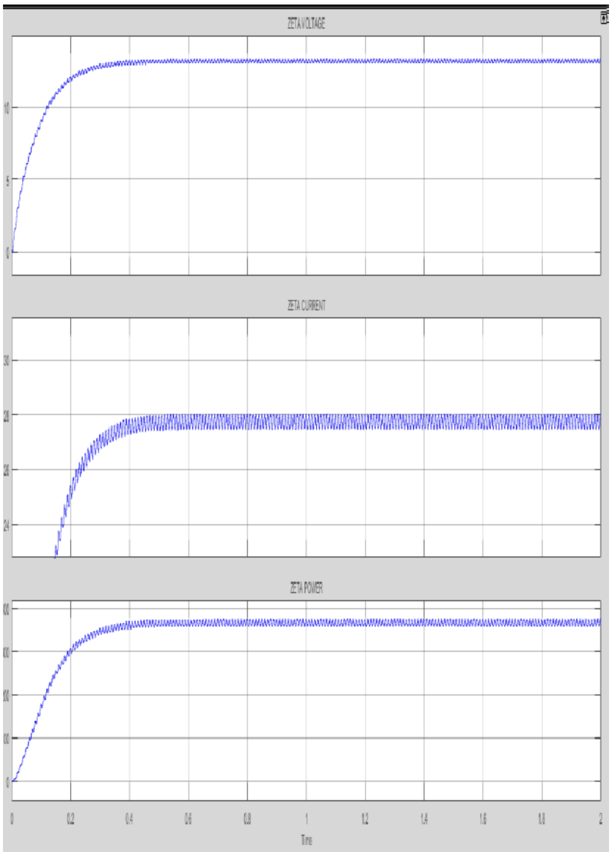

Fig. 3: Output Voltage, Output Current and Output Power of Zeta Converter.

The switch S_3 was triggered at suitable instant and was operated in buck mode. The plot below in fig 4, shows the output of multiport converter, when it is operated in buck mode. The converter delivers an output of 1V, 5A and 5W.

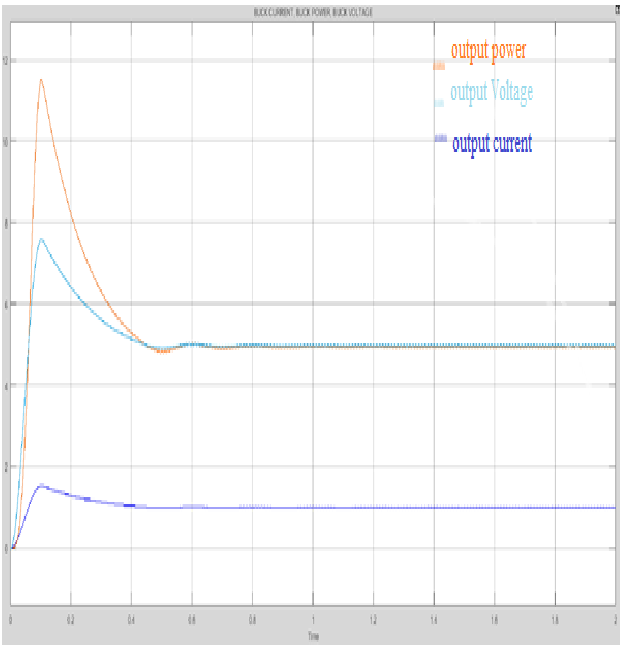

Fig. 4: Output Voltage, Output Current and Output Power of Buck Converter.

The fig 5,shows the comparison plot of the output voltage in zeta and in buck mode. The converter when operated in zeta and buck modes ,shows that the ouptut voltage of buck converter shoots upto 7V for a few sec and drops down at 5V.and settles there, that can applied for battery charging, etc.

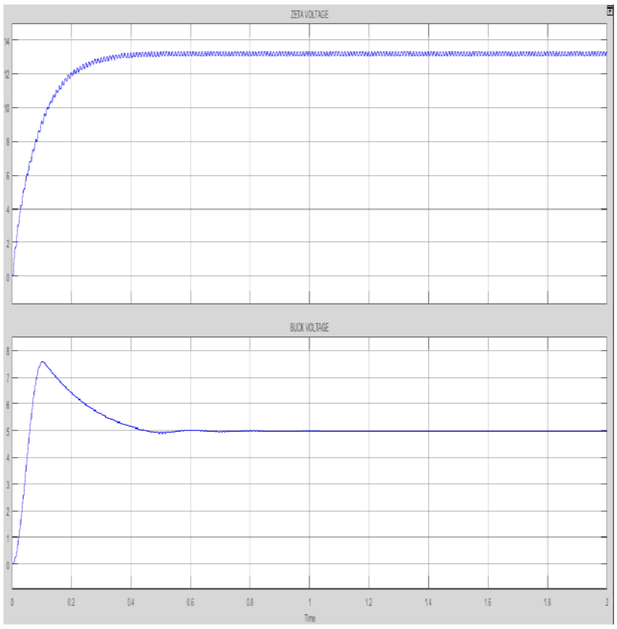

Fig. 5: Comparison of Output Voltage of Zeta and Buck Converter.

5. Hardware implementation

The circuit has been implemented and tested for two different laod conditions, i.e. for high and low power applications.

Table 1: Shows the Values of Different Parameters/ Components Used In the Circuit

Parameter / Components	Value
Supply Voltage, Vs	230 V
Input Filter Inductor, Lf	7.5mH
Input Filter Capacitor, Cf	2200 μF
Switching Frequency , fs	15 KHz
Turns Ratio, N1/N2	3.6
Output Inductor of Zeta Converter, Lo	350 μH
Output Capacitor of Zeta Converter, Co	36mF
Output DC Voltage of Zeta Converter, Vo	13 V
Output DC Current of Zeta Converter, Io	28 A
Output DC Voltage of Buck Converter, Vo	5V
Output DC Current of Buck Converter, Io	1A
Output Power in Zeta mode, Po	376 W
Output power of Buck mode,Po	5W

The hardware circuit board includes, the rectifier and filter circuit called the supply circuit. This is followed by the main circuit, the multiport circuit. The switches are triggered by the pulses obtained from the driver circuit. A PIC microcontroller PIC16F877A controls the entire circuit. It generates the necessary pulses at suitable instants and operates the converter in both zeta mode and buck mode.

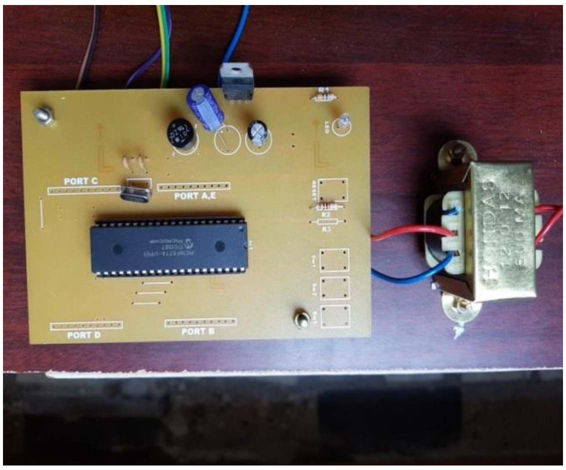

Fig. 6: Controller Circuit.

The fig 6 shows the controller circuit, through which the switches in the converter are controlled.
The fig 7and fig 8 shows the output voltage recorded from the ac-dc converter, when the multiport converter is operated in zeta mode and buck mode respectively. When operated in zeta mode, it displays an output of 16.12V dc and when operated in buck mode, it shows an output of 7.58V. The former can be applied for larger power applications and the latter mode could be applied for low power applications.

Fig. 7: Output Voltage when Operated in Zeta Mode.

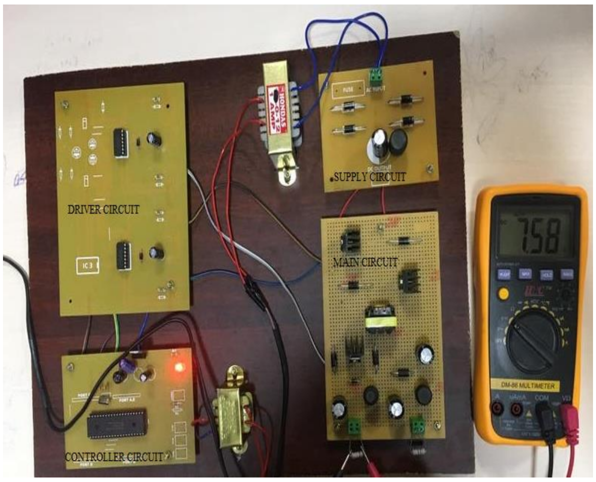

Fig. 8: Output Voltage of Buck Converter.

6. Conclusion

The proposed ac-dc converter involves a single stage conversion that could result in giving two different outputs, one with a high power that could supply for lighting purposes and the other with a low power for battery charging applications. The circuit internally provides over current protection. The circuit is capable of giving a constant output voltage, even if there are input supply variations. The switching stress is lesser during this conversion process. The PI controller tunes the circuit suitably thus feeding different loads. The multiport converter involved in the dc-dc conversion gives a constant output voltage, even if there variations in the supply side. The circuit is adaptable for multiple outputs that could feed multiple loads.

References

[1] F. Jauch and J. Biela, “Single-phase single-stage bidirectional isolated ZVS AC-DC converter with PFC,” 2012 15th International Power Electronics and Motion Control Conference (EPE/PEMC), Novi Sad, 2012, pp. LS5d.1-1-LS5d.1-8. https://doi.org/10.1109/EPEPEMC.2012.6397479.
[2] Arillaga, J., Joosten, A.P.B., and Baird, J.F.,‘Increasing the Pulse Number of AC-DC Convertors by Current Reinjection Techniques’, IEEE Trans. Power Apparatus and Systmes 102, (8), pp. 2649–2655.
[3] B. Singh, S. Gairola, B.N Singh, A. Chandra, K. AlHaddad, "Multipulse AC/DC Converter for Improving Power Quality: A Review” IEEE Trans. on Power Electronics, vol. 23, no. 1, Jan. 2008, pp. 260-281. https://doi.org/10.1109/TPEL.2007.911880.
[4] M. S. Hamad, M. I. Masoud and B. W. Williams, "Medium-Voltage 12-Pulse Converter: Output Voltage Harmonic Compensation Using 12-Pulse Converter: Output Voltage Harmonic Compensation Using a Series APF,"IEEE Trans. on Indus. Electron., vol. 61, no. 1, pp. 43-52, Jan. 2014.
[5] Araujo-Vargas, A. J. Forsyth and F. J. Chivite-Zabalza, "Capacitorv Voltage-Balancing Techniques for a Multipulse Rectifier With Active Injection," IEEE Trans. on Ind. Appl., vol. 47, no. 1, pp. 185-198, Jan.-Feb. 2011. 198, Jan.-Feb. 2011.
[6] Xiang Zhou, Jianping Xu, Xuejian Chen and Shu Zhong, “Soft-switching step-up/down DC–DC converter with bipolar outputs” Electronics Letters 4th August 2016, Vol. 52 No. 16 pp. 1404–1406. https://doi.org/10.1049/el.2016.1520.
[7] Gierri Waltrich, Jorge L. Duarte, and Marcel A. M. Hendrix,“Multiport Converter for Fast Charging of Electrical Vehicle Battery”, IEEE Transactions On Industry Applications, Vol. 48, No. 6, November/December 2012, Pp 2129-2140. https://doi.org/10.1109/TIA.2012.2226694.
[8] Jianwu Zeng,Wei Qiao, Liyan Qu, and Yanping Jiao,“An Isolated Multiport DC–DC Converter for Simultaneous Power Management of Multiple Different Renewable Energy Sources” IEEE Journal Of Emerging And Selected Topics In Power Electronics, Vol. 2, No. 1, March 2014, Pp 70-79. https://doi.org/10.1109/JESTPE.2013.2293331.
[9] X. Zhang, X. Ruan, H. Kim, and C. K. Tse, “Adaptive Active Capacitor Converter for Improving Stability of Cascaded DC Power Supply System,” IEEE Trans. Power Electron., vol. 28, no. 4, Apr 2013, pp. 1807-1816. https://doi.org/10.1109/TPEL.2012.2213268.
[10] S-H. Cho, C-S. Kim and S-K. Han,“High-Efficiency and Low-Cost Tightly Regulated Dual-Output LLC Resonant Converter”, IEEE Trans. Ind.Electron, vol. 59, no. 9, Jul. 2012, pp. 2982-2991. https://doi.org/10.1109/TIE.2011.2170391.
[11] Hao Zhang,Yuan Zhang, and 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, pp 4212-4224. https://doi.org/10.1109/TPEL.2012.2191161.
[12] P. Patra, A. Patra, and N. Misra, “A single-inductor multiple-output switches with simultaneous buck, boost and inverted outputs,” IEEE Transactions On Power Electronics, vol. 27, no. 4, pp. 1936–1951, Apr. 2012. https://doi.org/10.1109/TPEL.2011.2169813.
[13] Rong-Jong Wai, Kun-Huai Jheng, “High-Efficiency Single Input Multiple Output DC-DC Converter,” IEEE Transactions on Power Electronics, Vol.28, No.2, February 2013. https://doi.org/10.1109/TPEL.2012.2205272.