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SIMILITUDE INVESTIGATION ON ACTIVE POWER FACTOR CORRECTION MECHANISM EMPLOYING ZETA CONVERTER WITH DIODE AND SYNCHRONOUS MODE OF RECTIFICATION

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Abstract

Effective use of electricity is identified by means of an important parameter called power factor. This paper introduces the conversion of AC-DC by means of incorporating a zeta converter. Improvement of power factor has become an important phenomenon in order to harvest the necessary output. It thereby improves the voltage and maximizes the current carrying capacity and reduction of loss of power. Due to the harmonics enhancement the fundamental frequency gets varied which results in increase of the total harmonic distortion (THD) when this condition occurs, we observe that loss of power has increased. To reduce the increase of THD, we are in the position to develop and implement a converter suitable for the power factor correction. Upon literature survey various methods have been introduced along with the available converters. Here we use DC-DC zeta converter which has lower output voltage ripple and smooth compensation where synchronous mode of rectification is illustrated. A comparative analysis is done for both synchronous and diode rectification and it is noted that the results are highly satisfactory which gives better load transient results on simulation through MATLAB / SIMULINK. The response of the system can be witnessed by generating a step load change at the input side.

Keywords— *power factor, dc-dc zeta converter, THD, diode rectification, synchronous rectification*

INTRODUCTION

As we look into the Indian protocols of electricity generation, transmission and distribution it is sufficient and a known factor that a 50Hz frequency is employed for all electrical utilization and power supplies. The input quantities are either direct or alternating in nature and the output is harvested depending on the requirements and other intermediate blocks inserted in the circuits. Apparently we notice that most of the industries and other works which primarily depends on electricity are satisfied by using an AC source. But an output cannot be recorded without using DC source [1] – [4]. So it becomes a necessity of installing AC to DC conversion step up in the application needed. Introducing a rectifier unit is easy to and cost efficient too. But it remains ineffective if it does not meet the demand of the consumer. That is we are in the position to maintain a power factor to unity. So as to obtain the necessity output and the transfer of energy from the source to the main is to be done effectively. Since the power factor is the ratio of the real power to the apparent power eventually the reactive power consumption into the diminished thoroughly. Various methods are available for improvement of power factor [5], [6]. Primarily it is done by using power factor correction circuits. These power factor correction circuits in turn maintain the power factor to unity by stabilizing the sinusoidal and pulsating current. While incorporating these devices, several pulses of current are drawn from the AC network. Since the basic operation is performed in continuous and discontinuous mode. Chances are high in using of fundamental odd harmonics. Harmonics can be of nth order type and higher order harmonics are neglected while the lower order harmonics are to be treated with some methodologies. Along with the harmonics created we can observe several losses in the capacitors introduced in the circuit [7] – [14]. It is also important to note that PFC is not present then high amount of harmonics is seen along with very poor quality of power which in turn affects the entire grid network. Harmonics are never meant to be good and hence it is grasped from the knowledge obtained through the fundamentals of power electronics.

Two methodologies such as active and passive control strategies is done for the eradication of harmonics. When a passive filter is injected in to the circuit it reduces the harmonics but the problem is not completely solved. Despite the power factor increased satisfactorily.

Keeping into account, active power factor correction is done and this is done through zeta converter approach. Although the correction of power factor is performed using several other methodologies. We have chosen zeta converter owing to the advantages and its necessity of being introduced in this correction approach is that it gives better results than other converters which was use conventionally.

In this proposed literature, active power factor with zeta converter is elaborated. Since an alternative converter instead of a hybrid active converters like buck, boost and buck - boost are used. The usage of zeta converter is justified here. Therefore this paper focuses on power factor correction with the help of zeta converter under active approachable mode owing to demerits of other converters. It is observed that the zeta converter is been operated under continuous conduction mode aiming to harvest the required output.

The chosen zeta converter is then injected to a synchronous rectifier where replacement of diodes is done by using a MOSFET under continuous conduction mode of operation and it is evident that synchronous rectification provides better results with respect to the use of diodes.

ZETA CONVERTER

The paper written here majorly focuses on a comparison between the modes of rectification incorporated in any of the converter topologies. Here we come with a converter which requires lesser compensation and shows lower ripple voltage. Apparently this is a converter with a degree of order 4 alongside several real and complex poles and zeroes. Since we need a lesser compensation this converter is chosen as it doesn't own a zero at the right side of the plane and hence it is compensated easily also this uses a buck controller which drives high side MOSFET.

Owing to the advantages and disadvantages of this converter, proper study is done through many literatures and finally a converter with two inductors and conductors called a ZETA converter is taken for the investigation.

Zeta converter exhibits two different modes in operation under CCM mode as shown in the figures.

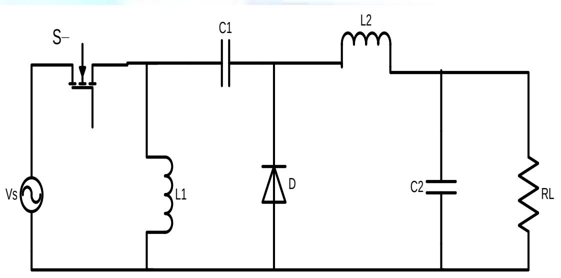

Fig. 1 Equivalent circuit of DC-DC ZETA converter

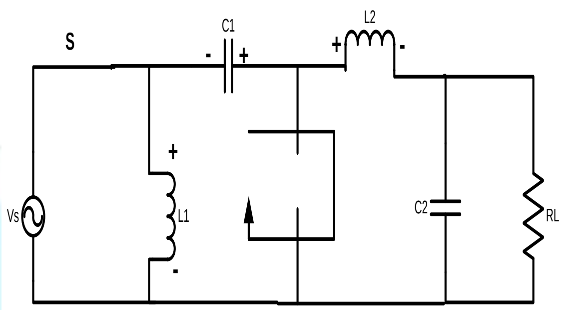

Fig. 2 During ON stage

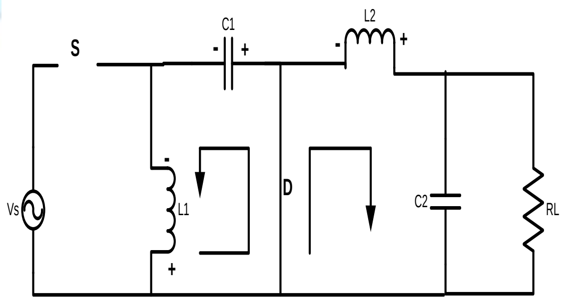

Fig. 3 During OFF stage

A. Design of DC-DC ZETA Converter

Consider the specifications of DC-DC ZETA converter parameter values are as follows Duty cycle D=0.628; Load Resistance R_L= 50 ohms; Switching frequency f_s = 25 KHz; ΔIL_1= 2.5A; $\Delta Vc1$=0.06V

$$L_1 = \frac{DV_{in}}{\Delta I_{L1} f_s}$$

L_1= 1mH

$$L_2 = \frac{(1-D)V_0}{\Delta I_{L2} f_s}$$

L_2 = 1mH

$$C_1 = \frac{D}{V_{in} f_s R_L}$$

C_1 = 10μF

$$C_2 = \frac{D}{8 f_s \Delta V_{C2}}$$

C_2 = 1000μF

SYNCHRONOUS RECTIFICATION

In order to accomplish better efficiency without much physical limitations and to encounter the basic demands the designers of the power supply area followed a new methodology called as SR. This does the same performance of the diodes eliminating the drawbacks seen in the diode rectification process. The basic concept is that usage of MOSFET is employed to reach the performance exactly seen by the diodes thereby improving the efficiency, higher reliability, proves to be the easiest way of approaching the manufacturers and many more which eventually diminishes the overall value and price of the other approaches.

Several demerits of diode rectification is observed as when the FET is under operating condition it exhibits energy to the output inductor and the load and when it is under rest condition commutation problem occurs. Fig. 4 shows the internal structure of synchronous rectifier.

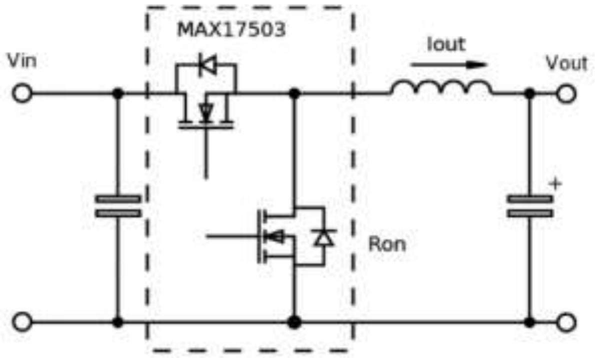

Fig. 4 Synchronous rectifier

Apparently, a MOSFET used in place of a diode gives significantly smaller voltage drop than the diode at a given constant current. This shows the effectiveness of SR and hence it shows sensitivity towards efficiency, size of the converter and the thermal behaviour of these handheld devices.

Further we can notice that MOSFET manufacturers show greater interest in incorporating new technologies which is used for SR [17].

Perks of synchronous rectification includes higher rating performance with improved efficiency, consumption of less power and inherently optimal current sharing when synchronous FETs are paralleled.

It is for this reason that these rectifiers are known as synchronous rectifiers because it is timed correctly in synchronism with its corresponding waveforms. Implementing SR in isolated converters improves the performance greatly.

Experimental Results and Analysis

The strategy of active power factor correction method is incorporated in this proposed article, it is mandatory to perform experimental analysis and the major outcome is harvested by a comparative study on both synchronous and diode rectification in agreement with voltage ripple factor. This is done by performing few steps so as to obtain the satisfactory result.

An internal voltage of 28 V DC input voltage is injected and the comparative study is based on the parameters including duty cycle, losses and the DC Voltage.

It is suggested to vary the duty cycle from 0.3 to 0.7 and the losses is compared at 20 kHz and 40 kHz whereas the DC voltage is controlled by means of electronic load with an initial volt if 0 W to 160 W with 20W interval.

A. The Performance Comparison between Synchronous rectifier and diode rectifier of ZETA Converter

It is seen that the ZETA converter employing synchronous rectifier results in improved input ripple voltage whereas not satisfactory in output ripple voltage as shown in the figures.

Fig. 5 shows the advantage of using zeta converter with synchronous rectification than diode rectification in terms of efficiency.

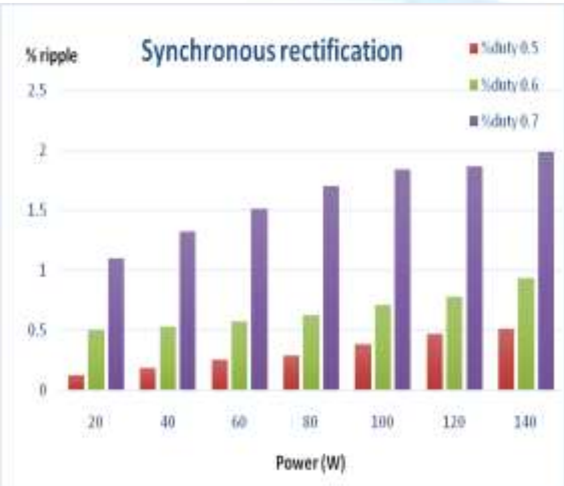

Fig. 5 The output voltage ripple factor at 0.5-0.7 duty cycle using (a) diode rectifier (b) synchronous rectifier

B. Investigation under 20 kHz and 40 kHz switching frequency

On comparing the models of both synchronous and diode rectification mode, we observe that the synchronous rectification gets the highest value interms of efficiency. The peak efficiency value shoots to 93% and diminishes to 85.6% at half the amount of the duty cycle.

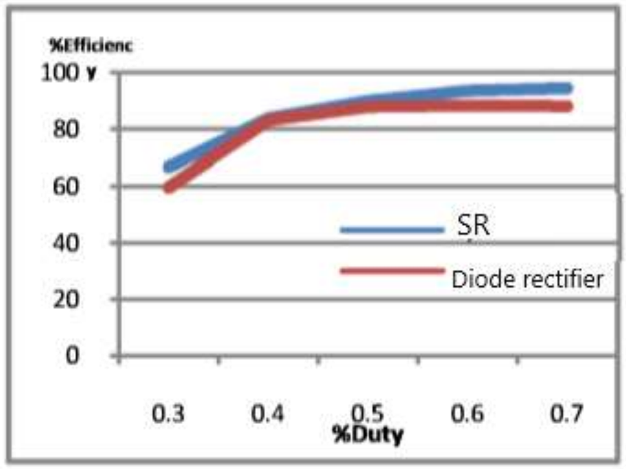

Fig. 6 Measured efficiency of Synchronous rectifier and diode rectifier of ZETA converter at 20 kHz and 40 kHz

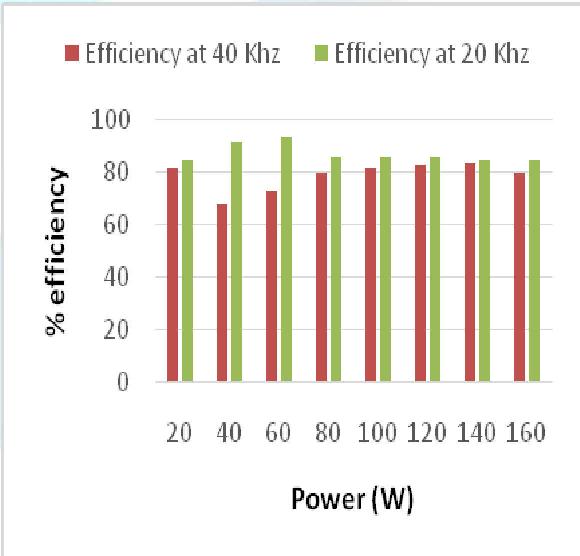

Fig. 7 Comparison of efficiency at different operating frequencies using (a) diode rectifier (b) synchronous rectifier

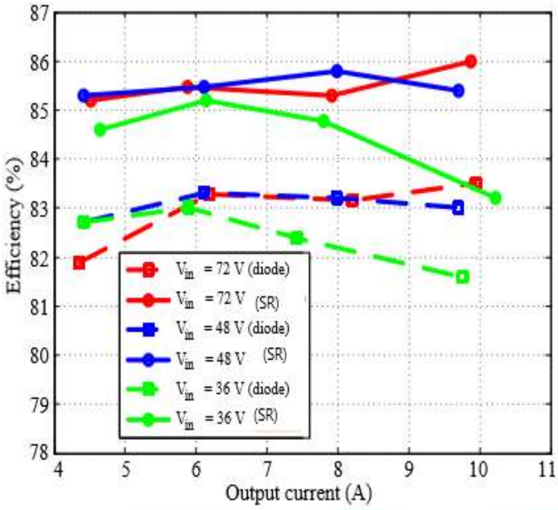

Fig. 8 Comparison of output current and efficiency with and without the proposed system at different operating conditions

Fig. 8 depicts the efficiency which is recorded for both modes of rectifications. And it is seen that the zeta converter employed with diode rectifier shows 83% efficiency and on a comparative note the efficiency is increased by 2.5% nevertheless the input voltage remains constant. And from this it is inferred that there is no change in the input voltage and it wholly depends wholly on the output power which eventually be the reason for increasing the efficiency.

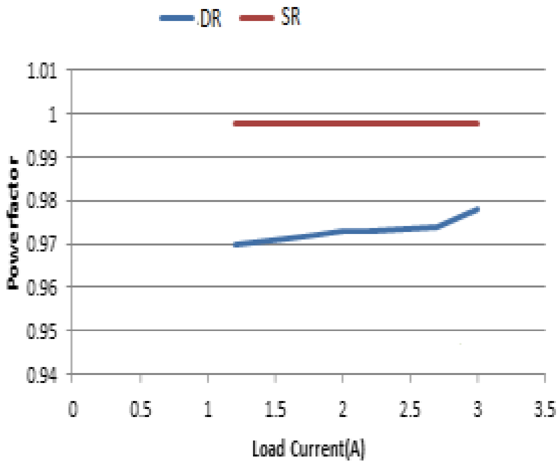

Fig. 9 Power factor at variable load current

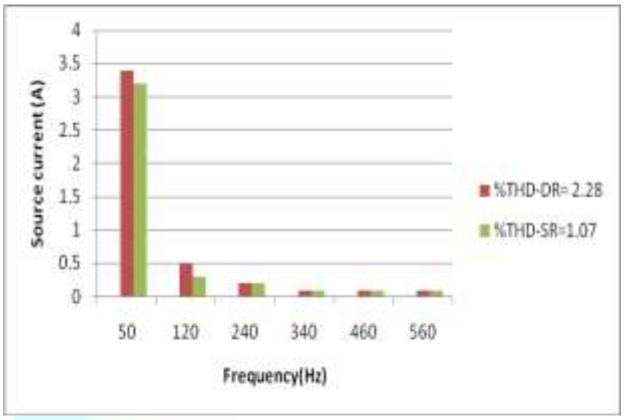

Fig. 10 Comparative analysis THD spectrum of source current

CONCLUSIONS

The accomplishment of the proposed literature is to compare and contrast the values obtained upon matlab simulation of incorporating both diode and synchronous rectifiers and thereby prove that the results recorded shows synchronous rectifier gives the satisfactory output upon observation.

On a note of observing the graph plotted against power and efficiency with efficiency plotted accordance with the frequency range 20 kHz and 40 kHz we can see that an increase in the power shows a great increase in the efficiency at 20kHz until a supply of 100V is given and then the value diminishes. Similarly efficiency at 40 kHz is recorded for various power supplies starting from initial chosen voltage to the highest voltage where we can see the efficiency ranging from a maximum value to a lesser value.

Looking into the graph plotted using the readings obtained for diode rectifier, on a comparative study we see that the efficiency oscillates and power changes frequently and then come back to its initial state. A similar result is obtained for efficiency at 20 kHz.

Since the written article emphases on active power factor correction methodology a graph is drawn alongside load current and power factor and it is observed that the curve of diode rectification is improper whereas a powerfactor close to unity is seen in synchronous rectification.

THD spectrum also ensures that diode rectification showing a greater value in accordance with the synchronous rectification.

On a concluding note, through analysis of diode and synchronous rectifier by various means it is shown that introduction of synchronous rectifier for ZETA converter to gives the satisfactory result.

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