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ORIGINAL CONTRIBUTION

Comparative Study between PI controllers based Two phase and Three phase Interleaved Boost converter as Power Factor Corrector

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ABSTRACT

Boost converter is most widely used as active power factor corrector over other power factor correctors due to its ability of drawing continuous input current which can be manipulated by current mode control technique. However boost power factor corrector suffers from the problem of presence of ripples in the input current. This problem can be overcome by using interleaved boost converter. In this paper power factor correction is performed by average current mode control by using twophase and three phase Interleaved Boost converter. Here at first simulation is performed by PI controller based twophase interleaved Boost converter and then three phase interleaved Boost converter is used and comparison of performance is discussed.

Key words: Average current mode control, Interleaved boost converter, PFC, PI controller

1. INTRODUCTION

POWER FACTOR:

Power factoris a figure of merit that measures how effectively power is transmitted between a source and load network. It always has a value between zero and one. The unity power factor condition occurs when the voltage and current waveforms have the same shape, and are in phase.

Power factor is defined as the cosine of the angle between voltage and current in an ac circuit. If the circuit is inductive, the current lags behind the voltage and power factor is referred to as lagging. However, in a capacitive circuit, current leads the voltage and the power factor is said to be leading.

Power factor can also be defined as the ratio of active power to the apparent power.

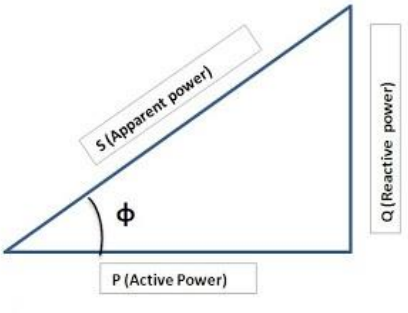

Figure 1: Power triangle

The power triangle is shown in Fig.1. The apparent power is given by the product of r.m.s. values of applied voltage and circuit current.

The active power is the power which is actually dissipated in the circuit resistance.

The reactive power is developed in the inductive reactance of the circuit.

Power factor = (Active power)/ (Apparent power)

NEED FOR POWER FACTOR IMPROVEMENT:

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Now a day there is a constant increasing demand of electrical and electronic apparatus. A lot of these apparatus require converting ac to dc power supply. This causes current pulses to be drawn from the ac network during each half cycle of the supply waveform, causing a low power factor. A load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. For example, if the load power factor were as low as 0.7, the apparent power would be 1.4 times the real power used by the load. Line current in the circuit would also be 1.4 times the current required at 1.0 power factor. The higher currents increase the energy lost and also the size and cost of all components of the system would be increased. Hence it has become very necessary to somehow improve the power factor.

THE PROBLEM OF POWER FACTOR IN SINGLE PHASE DIODE RECTIFIERS:

Single phase diode rectifiers are commonly used for ac-dc conversion. But the rectified dc voltage contains fair amount of ripple. To reduce this ripple a filter capacitor is used.
Although a filter capacitor suppresses the ripple from the output voltage, it introduces distortion in the input current and draws current from the supply discontinuously, in short pulses. The capacitor draws pulsating current only when the input ac voltage is greater than the capacitor voltage, which occurs at the line voltage peaks. So due to the use of filter capacitor the power factor becomes poor and introduces several problems including reduction of available power and increased loss. The waveform of the rectified voltage and distorted input current is shown in Fig.2.

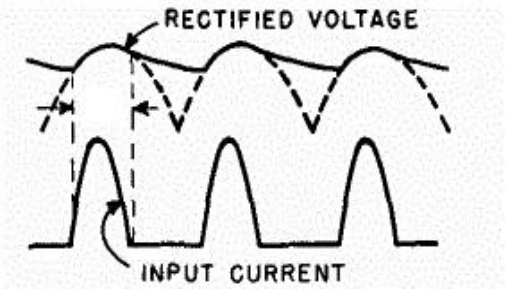

Figure 2 Pulsating input current waveform

1. Active Power Factor Correction (PFC)

In Passive PFC, only passive elements are used in addition to the diode bridge. Passive PFC can never attain power factor equal to 1 and obviously the output voltage cannot be controlled in this case.

So, for better performance Active PFC is used. An active PFC is a power electronic system that is designed to have control over the amount of power drawn by a load and in return it obtains a power factor as close as possible to unity. Commonly any active PFC design functions by controlling the input current of the load in order to make the current waveform follow the mains voltage waveform closely (i.e. a sine wave). A combination of the reactive elements and some active switches are in order to increase the effectiveness of the line current shaping and to obtain controllable output voltage.

2. Active Power Factor Correction using Boost Converter

Various converter topologies may be utilized for active power factor correction applications. Among these topologies, the boost converter topology (boost PFC topology) is utilized most frequently due to its advantages over other topologies [1], [2], [3]. The main advantage of the boost PFC topology is its continuous input current which can be forced to track the diode bridge rectifier output voltage. In this type of power convertervoltage obtained at the output stage is greater than that given at the input. The

circuit diagram of a boost converter is shown in Fig.3.

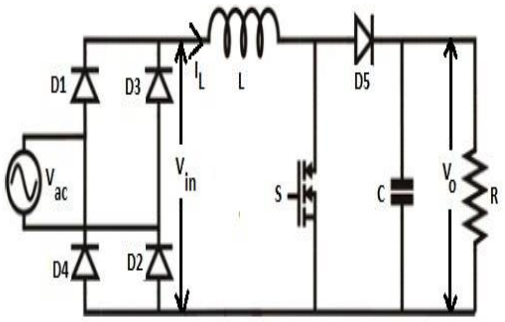

Fig.

Figure 3: Boost converter

The inductor has this peculiar property to resist any change of current in them and that serves as the main principle which drives a boost converter. The inductor acts like a load when it is being charged and acts as a source of energy when it is discharged.

The output voltage of boost converter is given by

$$V_o = \frac{V_{in}}{1-D} \qquad (1)$$

Here D is the duty cycle.

When switch S is on:

$$\frac{dI_L}{dt} = \frac{V_{in}}{L} \qquad (2)$$

Again when switch S is off:

$$\frac{dI_L}{dt} = \frac{V_o - V_{in}}{L} \qquad (3)$$

Here V_{in} is the rectified input voltage and V_o is the output voltage.

3. Average Current Control using PI Controller

Average current mode control allows a good input current waveform. Average current mode control using PI controller is represented in Fig.4.

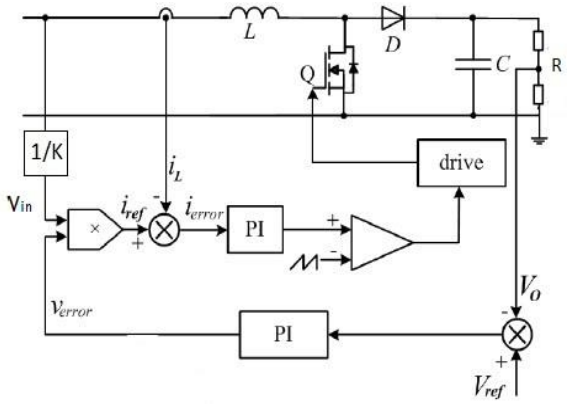

Figure 4: Average current mode control using PI controller

Here the boost PFC converter using average current mode control uses voltage control loop and current control loop. Input current i_L is compared with the reference current i_{ref}.The current reference i_{ref} is obtained by scaling down the line voltage by a resistive divider with scaling factor K and multiplying it with the error voltage v_{error}. The error voltage is obtained by comparing the output voltage with reference voltage passing it through the voltage control loop which is a PI controller. The comparison of $i_l$and i_{ref} gives the i_{error} which has been amplified by another PI controller, and compared with the sawtooth wave, and provides the PWM drive signal for the switch Q. The PI controllers consist of a proportional gain that produces an output proportional to the input error and an integration to make the steady state error zero.[4], [6]

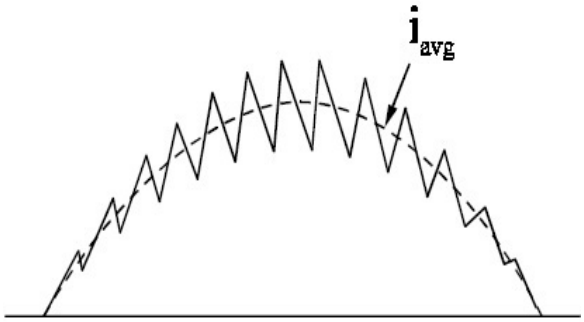

Figure 5: Average current mode control

In average current mode control the average inductor current is made to follow a sinusoidal reference.

4. Comparison of Two phase and Three phase Interleaved Boost Converter

In case of boost converter ripple is present in the input current due to rise and fall of the inductor current. This problem can be eliminated by using interleaved boost converter. This technique consists of a phase shifting of the control signals of cells in parallel operating at the same switching frequency. The main advantages are the current distribution. The current in the switches are just a fraction of the input current. So interleaved boost converters can reduce input current ripple and the switching losses. [5], [7], [8].

In two phase interleaved boost converter the control signal is phase displaced by 180°.

In three phase interleaved boost converter the control signal is phase displaced by 120°.

In case of three phase interleaved boost converter the total current is distributed amongst three switches. So, current specification required for switches in three phase interleaved boost converter is less than the two phase interleaved boost converter.

5. Simulation and Result

Diode Rectifier with Filter Capacitor

Diode rectifier with filter capacitor results in distorted current for resistive load.

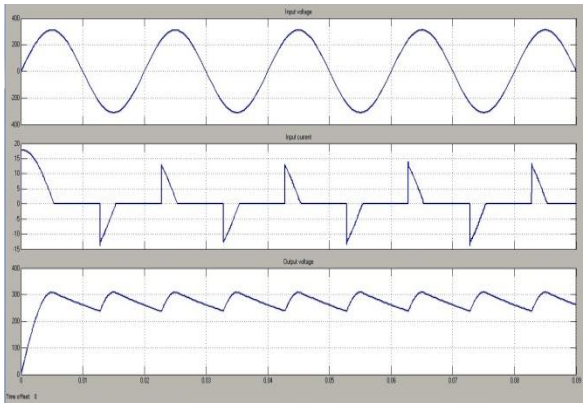

Figure 6: Input ac voltage, Input ac current and Output voltage waveforms

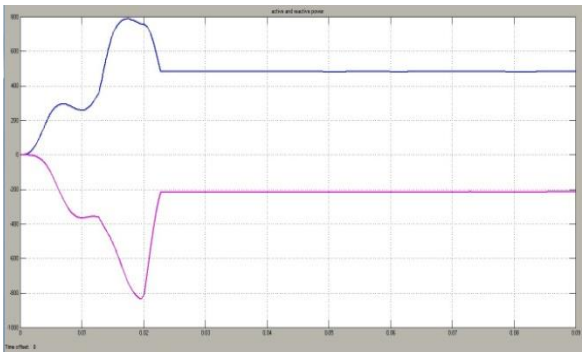

Figure 7: Active and reactive power waveform

For a resistive load due to filter capacitor deteriorated Power factor is 0.91.

Two phase Interleaved Boost Converter as PFC

In Two phase Interleaved Boost Converter total current gets divided amongst two switches. As the two inductor currentsare out of phase by 180°, so the total input current becomes ripple free and the current waveform is improved as shown in figure below.

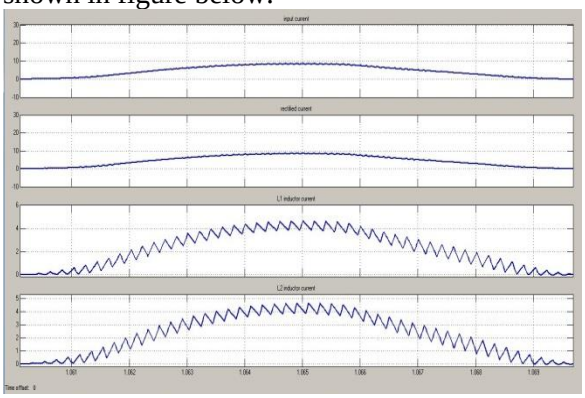

Fig.8. Ripples of input ac current, rectified input current, L1 inductor current and L2 inductor current

As we can see the maximum current through inductor is in between 4 to 5 A

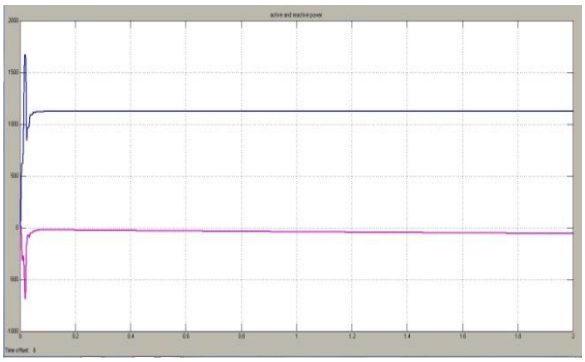

Figure 9: Active and reactive power waveforms for 2 phase interleaved boost converter

For same resistive load at a definite voltage of 400V the following results are obtained.
From Active and Reactive Power waveform the obtained power factor is 0.99

Three phase Interleaved Boost Converter as PFC

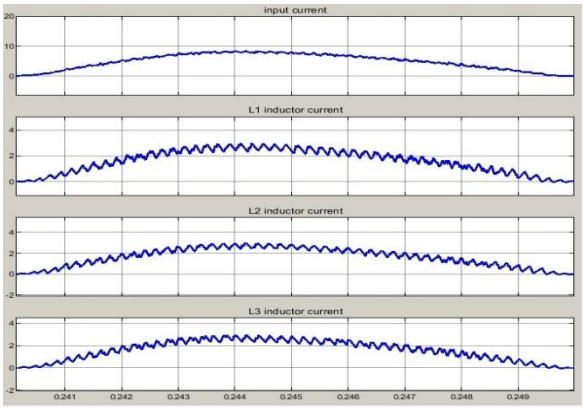

Figure 10: Ripples of input ac current, L1 inductor current, L2 inductor current, L3 inductor current

In Three phase Interleaved Boost Converter total current gets divided amongst three switches. As the three inductor currentsare out of phase by 120°, so the total input current becomes ripple free. From the current waveforms we can see that as the total current gets divided into three parts, so peak inductor current is much less than 4A. The reduced current specification for switches is the main advantage of three phase interleaved boost converter over two phase interleaved boost converter.

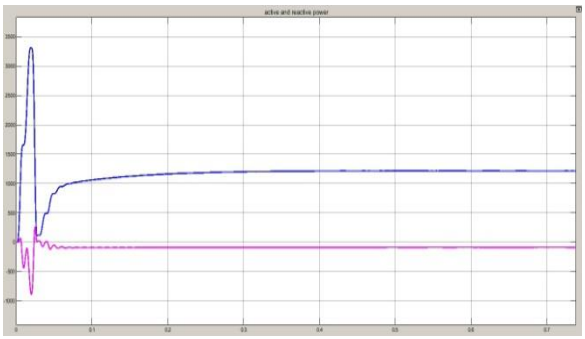

Figure 11: Active and reactive power waveforms for 3 phase interleaved boost converter

For same resistive load at a definite voltage of 400V the above results are obtained.
From Active and Reactive Power waveform the obtained power factor is 0.99. So Power factor obtained is close to unity as for two phase interleaved boost converter.

7. CONCLUSION

Energy conversion is the main issue of the power electronics and widely applied in today's world. Also we cannot compromise with the power factor. So For this purpose, modern power electronic converters are used with high power factor. In this paper both two phase and three phase interleaved boost converter with average current mode control using PI controller has been developed which is theoretically analyzed. Simulation results are also shown. We can conclude that both two phase and three phase interleaved boost converter improved the power factor to 0.99. Also it is noticed that for three phase boost converter reduced current specification required for switches compared to two phase boost converter.

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