DSP-BASED CURRENT SHARING OF AVERAGE CURRENT CONTROLLED TWO-CELL INTERLEAVED BOOST POWER FACTOR CORRECTION CONVERTER

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ABSTRACT

With rapid development in power semiconductor devices, the usage of power electronic systems has expanded to new and wide application range that include residential, commercial, aerospace, traction system and SMPS. The current drawn by power electronic system from the line is distorted resulting in a high Total Harmonic Distortion(THD) and low Power Factor (PF). Hence, there is a continuous need for power factor improvement and reduction of line current harmonics. This project on developing a circuit for power factor correction (PFC) using active filtering approach by implementing interleaved boost converters working in parallel. It is based on an optimized power sharing strategy to improve the current quality and at the same time to reduce the switching losses. Power factor correction (PFC) pre-regulators are used between the ac line and non linear load to improve the line current in terms of power factor and total harmonic distortion (THD). In medium and high-power applications, the interleaved boost PFC converter is the proper solution for this purpose to obtain a pre-regulator with lower size. The operation of the interleaved boost PFC converter provides a reduction of the inductor and electromagnetic interference filter volumes compared with those of the conventional single switch boost PFC converter. However, proper current sharing and current ripple minimization must been assured to achieve these benefits. The current sharing problem between the two-cell interleaved boost PFC converter is analyzed and discussed in this report and the resolved with usage of a digital signal processing (DSP)-based solution

Keywords: Boost PFC Converter, AC to DC Power Converter, DSP

I INTRODUCTION

Power factor is the ratio between the KW (Kilo-Watts) and the KVA (Kilo-Volt Amperes)drawn by an electrical load where the KW is the actual load power and the KVA is the apparent load power. It is a measure of how effectively the current is being converted into useful work output and more particularly is a good indicator of the effect of the load current on the efficiency of the supply system. All current flow will causes losses in the supply and distribution system. A load with a power factor of 1.0 results in the most efficient loading of the supply and a load with a power factor of 0.5 will result in much higher losses in the supply system[1].

1.1 Linear System

In a linear system, the load draws purely sinusoidal current hence the power factor is determined only by the phase difference between voltage and current. A linear load does not change the shape of the waveform of the current, but may change the relative timing(phase) between voltage and current. Thus,

Power Factor

$PF = cos\varphi$

Active Power

$P = V I cos\varphi$

Reactive Power

$Q = V I sin\varphi$

1.2 Non Linear System

A non-linear load on a power system is typically a rectifier (such as used in a power supply), or some kind of arc discharge device such as a fluorescent lamp, electric welding machine, or arc furnace. Because current in these systems is interrupted by a switching action, the current contains frequency components that are multiples of the power system frequency [1].

1.3 Power Factor

Power factor is defined as the cosine of the angle between voltage and current in an ac circuit. There is generally a phase difference 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. In a circuit, for an input voltage V and a line current I,

$$S^2 = P^2 + Q^2$$

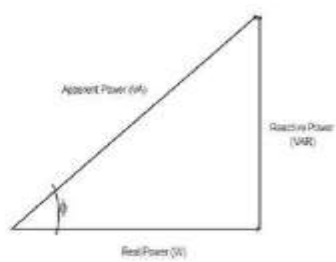

Fig. 1.The Basic Power Triangle

1.4 Significance of Power Factor

To better understand Power Factor (PF), it is important to know that power has two components:

• Real Power

• Reactive Power

Real Power is the power that is actually consumed and registered on the electric meter at the consumers' location. It performs the actual work, such as creating heat, light and motion. Real Power is expressed in kW and is registered as kWH on an electric meter. Reactive Power is required to maintain and sustain the Electromagnetic Field (EMF) associated with the industrial inductive loads. Reactive Power is measured in kVAR. The total required power capacity including the real and the reactive components is known as Apparent Power ,expressed in kilovolt ampere (kVA).

1.5 Distortion Power Factor

The distortion power factor describes how the harmonic distortion of a load current decreases the average power transferred to the load is the total harmonic distortion of the load current. This definition assumes that the voltage stays undistorted(sinusoidal, without harmonics). This simplification is often a good approximation in practice. *I*1*rms*is the fundamental component of the current and *I*2*rms* is the total current - both are root mean square-values. The result when multiplied with the displacement power factor (DPF) is the overall, true power factor or just power factor (PF):

$$Pf= \cos\varphi=\frac{1}{\sqrt{1+THD2}}$$

II.BASIC CIRCUIT TOPOLOGIES OF ACTIVE POWER FACTOR CORRECTION

Many circuits and control methods using switched-mode topologies have been developed with standard. The active PFC's can be implemented using several converter topology some of them are as below.

1. Buck Converter
2. Boost Converter
3. Buck-Boost converter
4. Cuk converter

We go for boost converter is most proper topology for PFC system.

Boost Converter

A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element .Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple

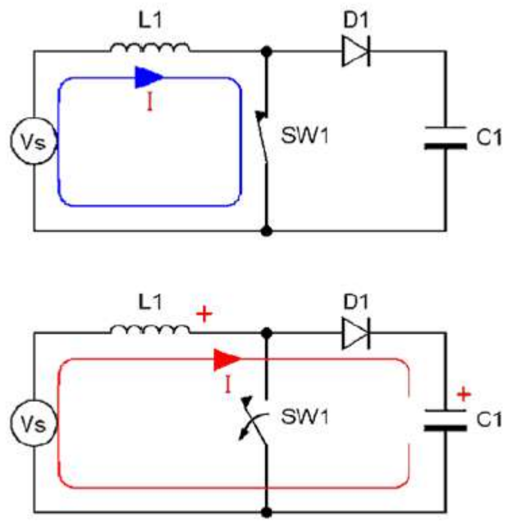

Fig. 2.Boost Converter operating circuit[3]

-in the On-state, the switch S is closed, resulting in an increase in the inductor current as shown in fig

-in the Off-state, the switch is open and the only path offered to inductor current is through the free wheeling diode *D*, the capacitor *C* and the load R .as shown in "fig".

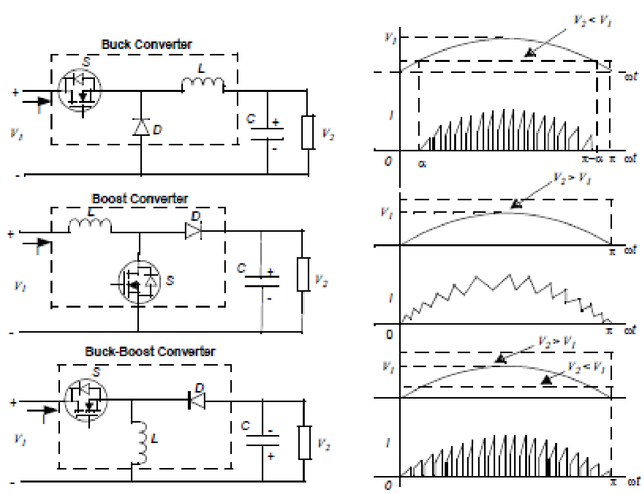

Fig. 2.Power conversion Topology

Type of	**Output**	**Cross**	**Line Current**
Buck	Positive	Yes	Always
Boost	Positive	No	Continuous
Buck-	Negative	No	Always

Table-1.Comparison of Different PFC Topologies

2.1 Boost Power Factor Correction Circuit

For the development of applications with sinusoidal current consumption more design work will be required than ever before. An active PFC also generates additional advantages, which does not generally lead to additional costs. Precondition is a system design that uses the advantages of an active PFC as smaller DC-link capacitor, loss reduction in the application connected to the output achieved by the increased and constant output voltage. Conventionally, boost converters are used as active Power factor correctors. Active Power Factor Correction (Active PFC)since it provides more efficient power frequency. Because Active PFC uses a circuit to correct power factor, Active PFC is able to generate a theoretical power factor of nearly unity. Active Power Factor Correction also markedly diminishes total harmonics ,automatically corrects for AC input voltage, and is capable of a full range of input voltage. Since Active PFC is the more complex method of Power Factor Correction, it is more expensive to produce an Active PFC power supply. Circuit diagrams for boost types of PFCs are as given below:

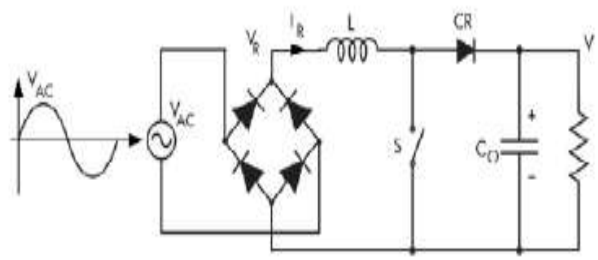

Fig. 3.Classical Power Factor Circuit

Advantages

1. Overall high efficiency.
2. Reduction of the development cost due to the modular design.
3. High reliability.
4. Reduction in the current ripple.
5. Reduction of conduction losses.
6. Size reduction of active and passive components as boost choke.

2.2 Types of Power Factor Correctors

Passive PFC

Harmonic current can be controlled in the simplest way by using a filter that passes current only at line frequency(50 or 60 Hz). Harmonic currents are suppressed and the non-linear device looks like a linear load. Power factor can be improved by using capacitors and inductors i.e. passive devices.

Active PFC

Here, we place a boost converter between the bridge rectifier and the main input capacitors. The converter tries to maintain a constant DC output bus voltage and draws a current that is in phase with and at the same frequency as the line voltage.

III. INTERLEAVED BOOST CONVERTERS

The concept of interleaving or more generally that of increasing the effective pulse frequency of any periodic power source by synchronizing several smaller sources and operating them with relative phase shifts. Interleaving technique actually exists in different areas of modern technologies in different forms The difference between an Interleaved PFC and a single stage PFC is that two or more boost converter are used for to supply the load. In high power applications, the voltage and current stress can easily go beyond the range that one power device can handle. Multiple power devices connected in parallel and/or series could be one solution. However, voltage sharing and/or current sharing are still the concerns. Instead of paralleling power devices, paralleling power converters is another solution which could be more beneficial. Furthermore, with the power converter paralleling architecture, interleaving technique comes naturally. Benefits like harmonic cancelation, better efficiency, better thermal performance, and high power density can be obtained. In earlier days, for high power applications, in order to meet certain system requirement, interleaving multi-channel converter was a superior solution especially considering the available power devices with limited performance at that time.

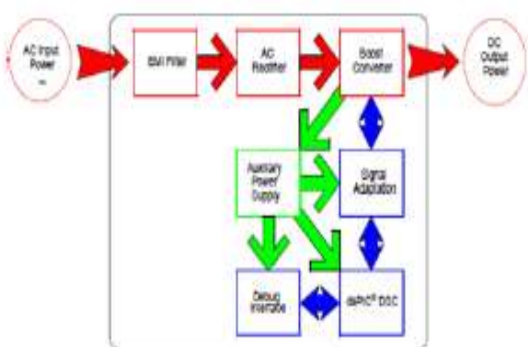

Fig. 4 : Block Diagram Of Interleaved Boost PF [3]

Advantages:

1. Interleaved PFC allows a more efficient power factor correction deign.
2. Interleaved PFC also reduces output current ripple.
3. Increased capacity to serve power requirements.
4. Better voltage regulation.
5. Lower energy and distribution costs.

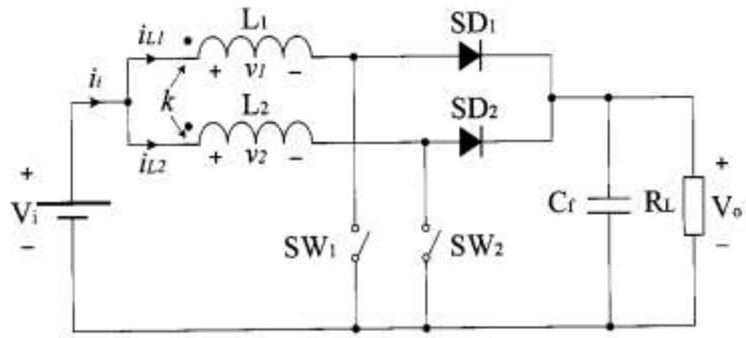

Fig. 5 .Interleaved Boost PFC

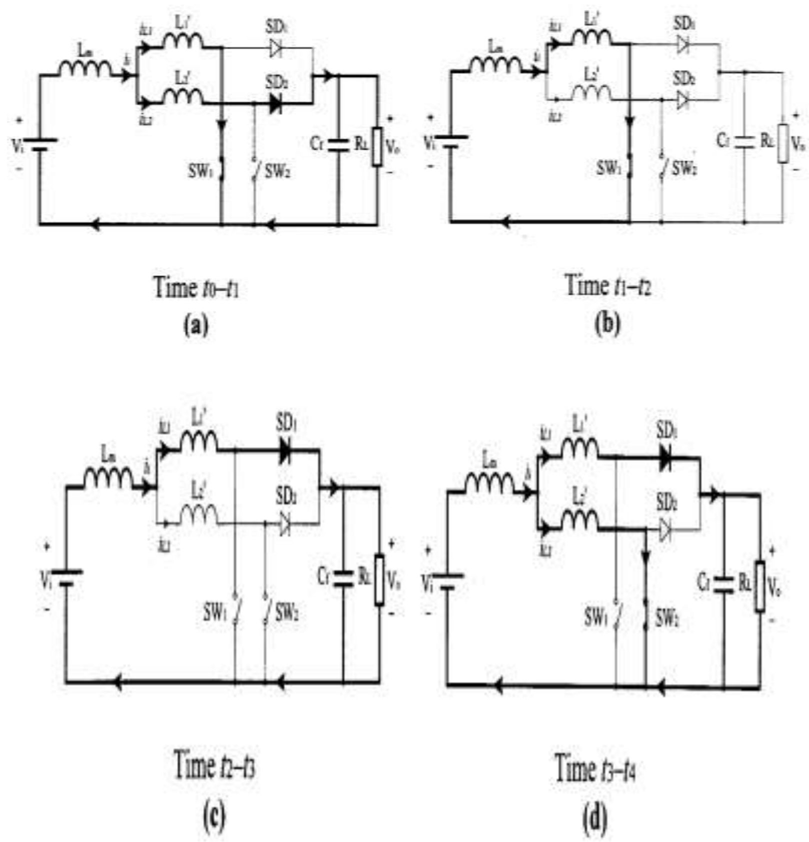

Fig. 6.Operation Of Interleaved PFC

State a- At time , SW is closed. The current in the inductor L1 starts to rise while L2continues to discharge. (The current inL2 was acquired in the last switching cycle.)

State b - At time , L1falls to zero L2continues to rise

State c - At time t2, SW is opened. The energy stored in the Inductor L1 is transferred to the load via the boost rectifier SD .

State d - The switch SW is closed at time t3. The current inL2 inductor starts to rise. L1 continues to discharge.

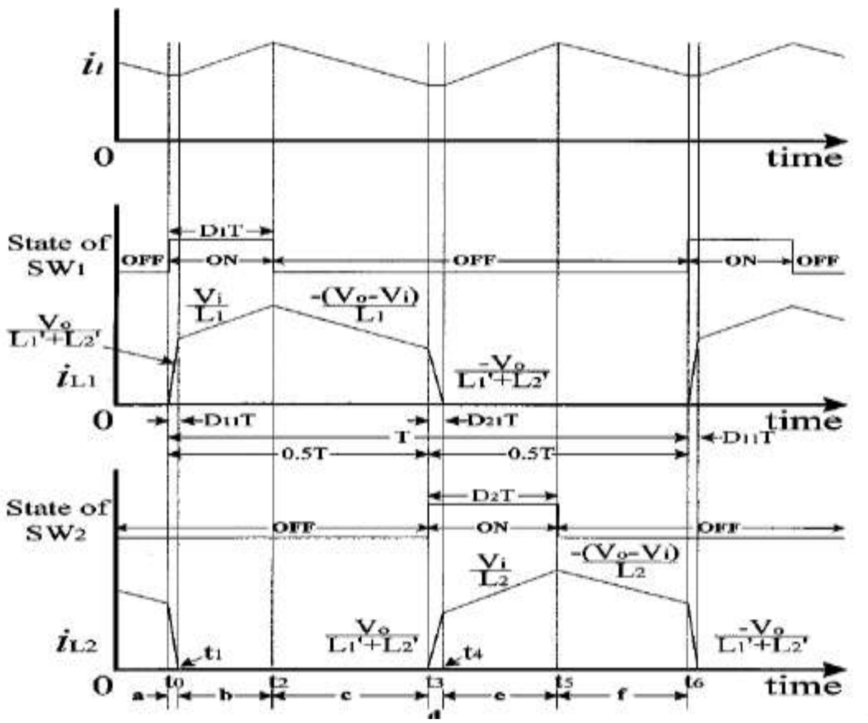

Fig.7 .Current Waveform Of Converter

IV.CONTROL TECHNIQUE

The main reason for the poor current sharing is that the slopes of the phase shifted ramps are unequal due to differences in the values of the timing capacitors and the charging currents. Power factor correction interleaved boost converters provide a reduction of the inductor volume and weight when compared with the conventional PFC boost converter. However ,to achieve this benefits proper current sharing and current ripple minimization must been sure[3].Conventional off-line switch-mode AC-to-DC converters draw pulsating ac line current from the utility grid, therefore, they produce a reactive fundamental component and high order harmonic components to the utility line. These result in

• Electromagnetic interference (EMI) and line distortion,

• Increase of rms current in the transmission line, and, thus, additional losses.

With increasing demand for more power capability and better power quality from the utility line, power factor correction techniques have attracted much more attention. Numerous methods have been proposed in recent years [2,6] to achieve unity power factor for the switch-mode power supply. Among them, the boost converter in the continuous conduction mode (CCM) with constant switching frequency is the most popularly used topology. The advantages are:

1. The input current is a smooth waveform, resulting in much less electromagnetic interference and therefore reduced input filtering requirements;
2. Current stress in the power switches is lower.

4.1 Requirement for PFC

1. Voltage Mode Control
2. Current Mode Control

1.Voltage Mode Control

The first approach developed to control SMPS applications is called Voltage Mode. Voltage mode is intuitive, the actual output voltage is compared to the desired output voltage and the difference (error) is used to adjust the pwm duty cycle to control the voltage across the inductor.

2.Current Mode Control

Current-Mode control was developed to correct some issues known with voltage mode. Current-mode uses the error between the desired and actual output voltages to control the peak current through the inductor. Current mode control provides inherent current limiting on a cycle by cycle basis.

3. Average Current Mode Control

The IPFC system uses the average current mode control method to meet the system requirements. The IPFC system uses the average current mode control method to meet the system requirements. For PFC, this control method is used to regulate DC output voltage while keeping the input current shape sinusoidal and in phase with the input voltage. The control method operates in Continuous Conduction mode in most parts of the operating regions of the converter. The operation is primarily based on the value of the load current at any point and the selection of the inductor.

V. CONCLUSION

In this paper, the problem of current sharing between the inductors of the interleaved boost PFC converter is pointed out and a DSP-based simple practical solution is use. In the proposed technique, the equal current sharing between two cells of an interleaved boost PFC is achieved by using predictive control strategy in which the active filtering approach can be utilized so as to further reduce the current ripples and switching losses. The switches can be made to be work under soft-switching condition. This whole entire system is controlled by using DSP Programmed.

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