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Analysis and comparison of current control methods on bridgeless converter to improve power quality

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ABSTRACT

In this paper, the performance analysis of power factor correction (PFC) current control methods is presented for a bridgeless converter operating under continuous conduction mode (CCM). The bridgeless converter has been proposed using proportional-integral control (PIC), average sliding control (ASC) and predictive current control (PCC) methods to obtain unity power factor (PF) and lower total harmonic distortion (THD) of input current. Several PFC methods have been developed to satisfy the international standards such as *IEC 61000-3-2* and *IEEE 519-1992*. The detailed steady-state theoretical analysis of the bridgeless converter is presented, which is verified by simulations and experiments carried out on 600 W and 50 kHz. The performance of the current control methods for the bridgeless converter is investigated by a Matlab/Simulink program. The experiments performed in the laboratory under input voltage and load variation ranges verify the theoretical and simulation studies. The control methods are programmed by the *TMS320F2812 DSP* microprocessor.

1. Introduction

In the past several years, non-linear loads (rectifiers, electric drills, UPS, computers, arc furnaces industrial electronic equipment contains of power semiconductors such as thyristor converters, and Inverters) are becoming an important part of the electrical load in industrial and commercial power system. These loads draw non-sinusoidal currents from the supply and lead to voltage distortion and simultaneously affect the power factor. Many efforts are being done to develop interface circuits which improve the power factor of the systems. To improve the power factor of AC side, power factor correction (PFC) converters are generally used, which actively adjusts input current waveform to sinusoidal waveform. The *PFC* converters are an important area of study and research in power electronics, used in practical power supplies to regulate output and to provide an acceptable ratio of active and apparent power [1–5]. There are different topologies used in *PFC* converters, such as boost, buck, flyback, bridgeless, and interleaved [6–10].

The most popular topology for these applications is the boost converter due to its simplicity, voltage step-up characteristic, efficiency and performance. The topology used in this study, is bridgeless converter working in *CCM* under average current mode control technique. It has one less diode in the line current path compared to the conventional boost converter. The topology of boost converter operates with bridge rectifier for AC input voltage. However, the bridgeless converter have reduced conduction losses as the line current simultaneously flows through only two semiconductors (a diode and a switch) instead of three (two diodes and a switch) [11–14].

Various control methods have been implemented into the *PFC* converters. These control methods get their fast development due to the requirement to meet the compliance of European standards for the regulation of low frequency current harmonics. The publication of specific international standards, such as *IEEE* and *IEC* [15,16] become one aspect of most important issue to arrange harmonic pollutions. The researchers develop more efficient power electronic systems to comply with these standards. In this study, the most popular control methods are reviewed and compared, in order to highlight advantages and drawbacks of each solution. These control methods are proportional-integral control (PIC), average sliding control (ASC), and predictive current control (PCC) methods [17–23].

The *PFC* control strategy is typically done with two loops: an internal and fast current loop to achieve near unity *PF*, and an external and slow voltage loop to stabilize the output voltage. The *PIC* method which is one of the main conventional control strategies is used in *PFC* control. The average inductor current, $|i_{in}|$ is forced to follow the reference current, I_{ref} which is proportional to the rectified voltage, so that unity *PF* is achieved [8,12,13]. The implementation of *ASC* for power converters usually involves two steps. First, to design an ideal *ASC* by means of an ideal sliding surface; second,

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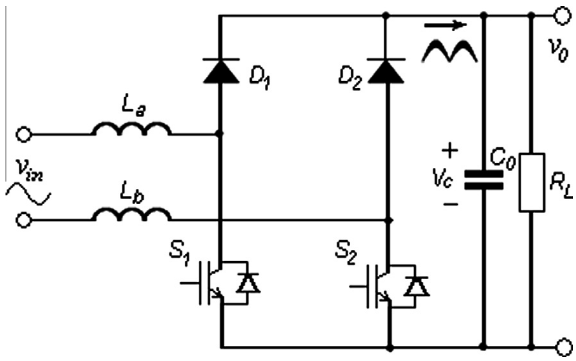

Fig. 1. Bridgeless *PFC* converter topology.

to modify the sliding surface in order to implement the control with a constant switching frequency, or at least with an upper limit for the switching frequency. Ideal *ASC* algorithms are usually simple; however, its implementation becomes difficult due to the necessity of the second design step [18,23]. Normally, in conventional power factor converters the output voltage is measured and compared with the reference voltage to obtain reference current. The generated reference current is compared with the measured inductor current to adjust the duty cycle of the converter switch. In these converters the output voltage of converter, inductor current, and the input ac voltage should be measured to adjust duty cycle to obtain unity *PF* operation. Using *PCC* method makes it possible to provide unity *PF* by measuring only the input and output voltages without needing to measure the inductor current. The control strategy is based on the prediction of the inductor current at each sampling instant, not feedback to achieve unity *PF* [19].

Many software programs used in the simulation of power electronics circuits. In this study, Matlab/Simulink program for the power electronics is used for the implementation of the control methods on the bridgeless *PFC* converter. Matlab/Simulink was designed for the engineering solutions. Due to existence of power electronics control block sets in this program, the simulation of control of electronic circuits can be possible and performed. This program includes all branches of electrical and electronics

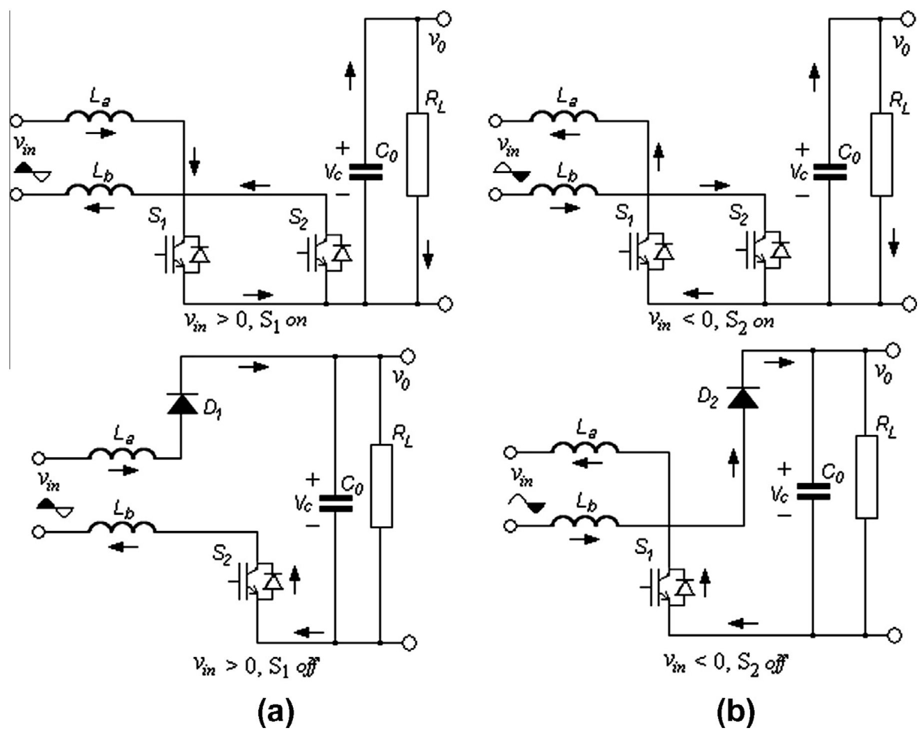

Fig. 2. Equivalent circuits of the converter for on/off states of the switches during; (a) positive half cycle, (b) negative half cycle.

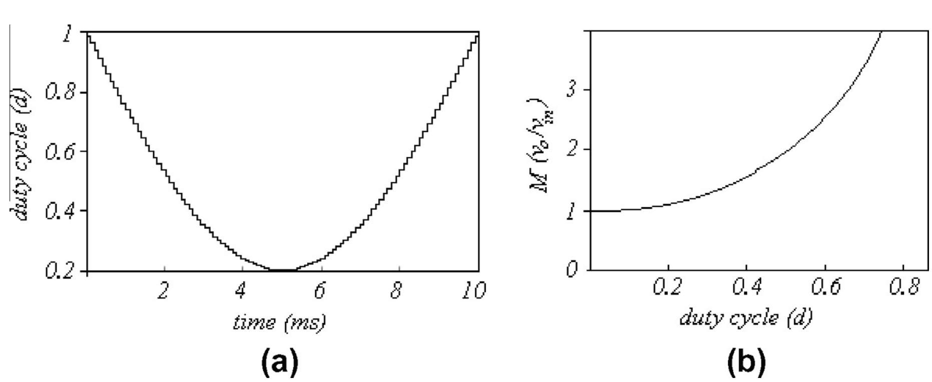

Fig. 3. Relationship between: (a) duty cycle as a function of time, (b) voltage conversion ratio *M* as a function of duty cycle.