# Research on Principle and Control Method of Totem-Pole PFC

**Chunjiang Liu, Chao Li, Weiyao Mei, Chunmei Xu and Lijun Diao**

**Abstract** Active power factor correction is an effective method to suppress harmonic current and improve power factor. One of the important developing directions of power factor correction circuit is to improve conversion efficiency. Among various kinds of power factor correction circuits, the Totem-Pole boost power factor correction circuit, as a bridgeless PFC, uses fewer devices and theoretically achieves higher conversion efficiency and better performance. In this paper, the working principle of Totem-Pole PFC is analyzed, a Totem-Pole PFC control scheme is proposed, and the SimCoder simulation tool is used for simulation. The feasibility of the scheme is verified through the simulation results.

**Keywords** Power factor correction · Bridgeless PFC · Totem-Pole · Control method

## 1 Introduction

With the development of power electronic devices and the wide application of power electronics technology in various industries, power electronic switching power supply devices connected to the power grid have gradually become the main source of harmonic injection into the power grid [1]. For example, in the subway station lighting system, due to the use of a large number of LED lighting devices,

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it will produce a large number of harmonic pollution without effective power factor correction. Therefore, the use of low-loss, high-efficiency PFC solutions is of great significance for reducing harmonic pollution and improving the effective utilization of electrical energy. The basic principle of the active power factor correction circuit is to use the control circuit to force the input current waveform to track the input voltage waveform to realize the sinusoidal of the AC input current and synchronize with the AC input voltage [2]. The conventional power factor correction circuit uses a rectifier bridge and has many disadvantages such as a large number of components and a large on-state loss [3–5]. The bridgeless PFC technology can theoretically achieve smaller conduction losses and improve efficiency by removing the rectifier bridge or reducing the number of power devices on the current conduction path. Among the various schemes of bridgeless PFC, the Totem-Pole bridgeless PFC has the advantages of minimum device, lowest conduction loss, high efficiency, and low common mode noise. So it has wide application prospects [6].

This paper analyzes the working principle of Totem-Pole PFC and proposes a Totem-Pole bridgeless PFC control scheme. And then, the feasibility of the scheme proposed is verified through SimCoder.

## 2 The Working Principle of Totem-Pole PFC

Figure 1 shows the circuit topology of the Totem-Pole bridgeless PFC converter.

The circuit topology includes a switching arm and a diode arm. The Totem-Pole PFC is equivalent to the boost circuit in both the positive half cycle and the negative half cycle of the AC power supply, so the output voltage is higher than the input voltage [7, 8]. Among them, $S_1$ and $S_2$ are MOSFETs, $D_1$ and $D_2$ are diodes, and $L$, $C$, and $R$ are inductance, capacitance, and resistance, respectively.

In the positive half cycle of the alternating current, when $S_1$ is turned on, as shown in Fig. 2a, the alternating current is charged to the inductor through the inductors $L$, $S_1$, and $D_1$, and the energy storage of the inductor is increased; when $S_1$ is turned off, as shown in Fig. 2b, the alternating current forms a loop through the body diodes of $S_2$, $R$, $C$, and $D_1$. The inductor $L$ and the power supply $V_{ac}$ discharge

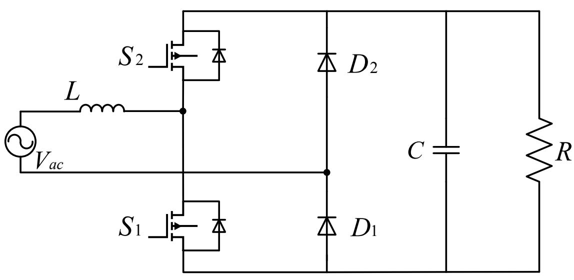



**Fig. 1** Topology of Totem-Pole PFC

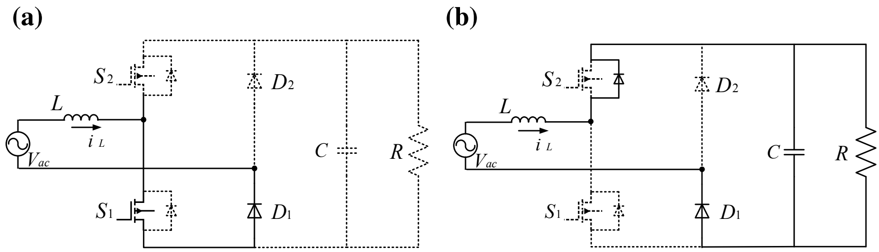



**Fig. 2** Operating condition of a positive half cycle of alternating current

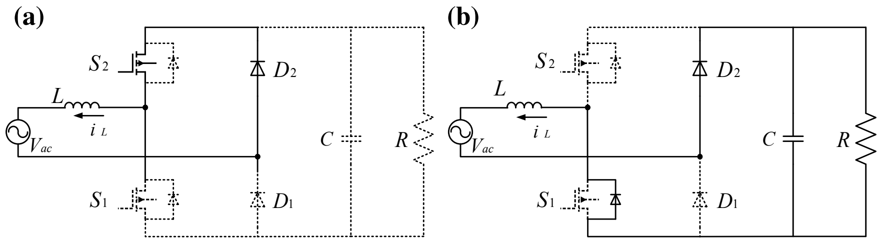



**Fig. 3** Operating condition of an alternating current negative half cycle

the capacitor $C$ and the resistor $R$. Hence, the output voltage is higher than the power supply voltage, and the energy storage of the inductor $L_1$ is reduced. The body diodes of the switches $S_1$ and $S_2$ then form a Boost PFC structure. During the positive half cycle of the sinusoidal alternating current, $D_1$ is continuously turned on and $D_2$ is continuously turned off.

The operating state of the AC negative half cycle is similar to that of the positive half cycle.

In the negative half cycle of the power supply, the inductive current is negative, $D_2$ is continuously on, and $D_1$ is continuously off, as shown in Fig. 3. The body diodes of $S_2$ and $S_1$ constitute boost PFC structure.

The two switches switch functions when the polarity of the input voltage changes. For example, when the voltage becomes negative after crossing zero, $S_1$ changes from being switched on as the inductance energy storage to its body diode conduction to supply power for the load, while $S_2$ changes in the opposite function. Therefore, the functions of the two switches are complementary and interchangeable with the change of polarity.

According to the analysis of working principle, the advantages of Totem-Pole PFC are fewer components, less loss, high efficiency, and relatively small EMI effect. It can be seen that the Totem-Pole PFC is a relatively complete and practical bridge-free PFC design scheme.

## 3 Control System Design

Switching converter control mode can be roughly divided into voltage control and current control. In the current control, according to the conduction mode of the inductive current, the working mode of the switching converter is divided into the continuous conduction mode (CCM), the discontinuous conduction mode (DCM), and the critical conduction mode (CRM) [9]. With the appearance and application of GaN high-speed MOS tube and other devices, the Totem-Pole PFC has been able to work in CCM mode. This design adopts CCM mode under average current control. The control of PFC usually adopts double-loop control, the outer loop is the voltage loop for stabilizing the output voltage, and the inner loop is the current loop for limiting the output current and improving the dynamic performance [10].

Figure 4 shows the working principle of the average current control mode, the current loop amplifier output signal $U_{ca}$ compares with PWM modulator constant slope $R_sM_s$, and produces control signal duty cycle $d$, the $R_s$ is the internal resistance of equivalent inductance sampling, $M_s$ slope is PWM ramp signals, voltage signals $U_{ca}$ is port voltage by partial pressure resistance, compared with a given voltage error voltage and after compensating voltage, and then as a reference voltage of the inner ring.

Figure 5 shows the schematic diagram of generating control signal duty cycle d, slope $R_sM_s$ is enables reference signal, its time cycle is equal to the switch signal the time period of $T_s$, sampling the voltage error amplifier output signal $U_{ca}$, the signals

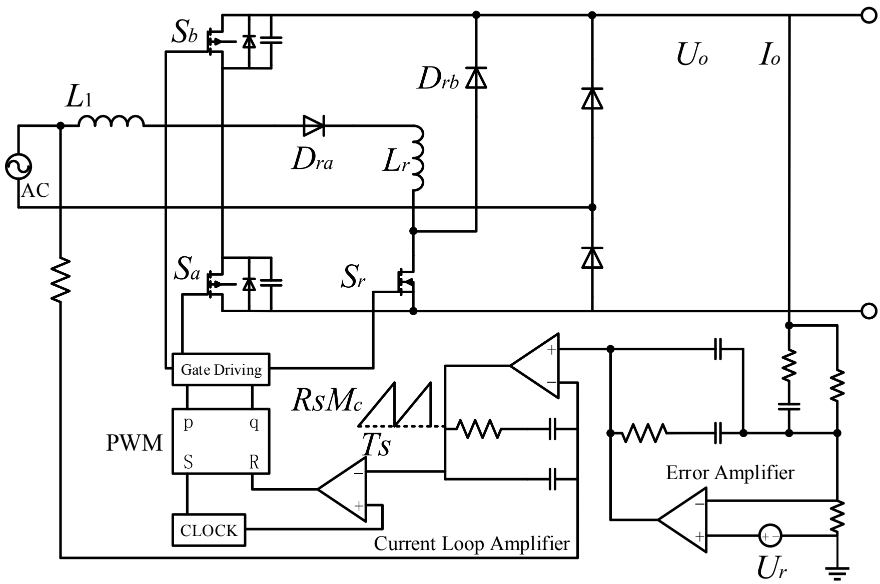
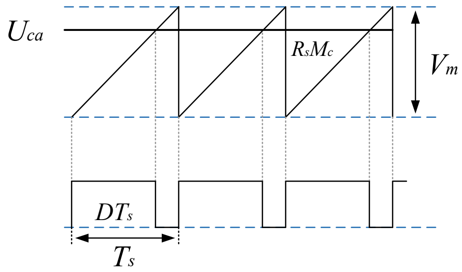



**Fig. 4** Working principle of the average current control mode

**Fig. 5** Schematic diagram of duty cycle generation




is greater than the slope $R_sM_s$ time to switch enables the opening of the time, need the time compared to the cycle time is the duty ratio.

## 4 Simulation and Experiment

The design parameters of Totem-Pole PFC converter are as follows:

$$P_o = 115\text{W},\ \text{V}_o/\text{f} = 40\text{V}/60\ \text{Hz},$$
$$V_d = 70\text{V},\ \text{PWM dead zone time} = 2\ \mu\text{s},$$
$$L = 1.323\ \text{mH}, \text{C} = 330\ \text{F}.$$

Current loop: This control architecture adopts the double-loop average current control architecture and adopts the type II controller. However, the low-pass part is placed in the sensing loop ($fc$ = 20 kHz), and the controller itself adopts the proportional integral to control. In addition, a forward control signal is added to the control voltage of PWM.

Voltage circuit: Voltage loop resistance to design with full load, $R$ = 49 Ω, and thus, there are

$$H_{dc}(s) = \frac{26.21}{s + 61.84} \tag{1}$$

Set $fc = 20$ Hz, $\omega c = 125$ rad/s, choose $p = 180$ rad/s, $z = 30$ rad/s, then

$$Gv(s) = \frac{30(s + 30)}{s(s + 180)} \tag{2}$$

The SimCoder simulation tool of PSIM is used for simulation, and the simulation waveform is shown in Fig. 6. It can be seen from the simulation results that the input current waveform can well follow the input voltage waveform and be corrected to the standard sine wave. The output also meets the given requirements.

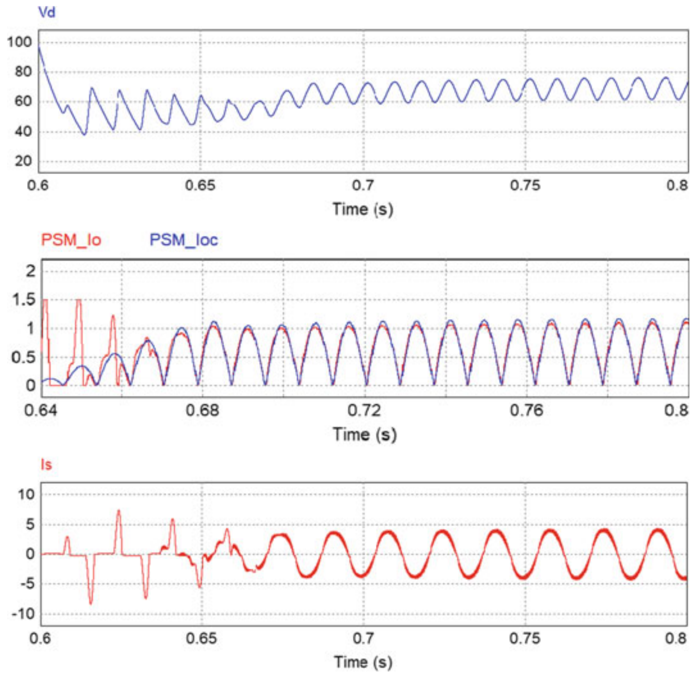



**Fig. 6** Simulation results of Totem-Pole bridgeless PFC SimCoder

# 5 Conclusion

In this paper, the advantages and application value of the Totem-Pole bridge-free PFC have been summarized, the working principle of the Totem-Pole bridge-free PFC has been analyzed, and the working modes of the topology in the positive and negative cycles of alternating current have been expounded. On this basis, the architecture of double-loop average current control in the continuous mode of inductance current has been presented, and the main key technical points are analyzed, and the corresponding solutions are proposed. The correctness and practicability of the scheme are proved by system simulation and experiment.

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