Chapter 56
Single Phase Soft Switching Techniques Power Factor Correction Converter

P. Anjappa, K. Naresh, V. Ramesh, P. Lakshmipathi and K. Reddy Swathi

Abstract This paper proposes a dual mode used to control a single phase soft switching boost power factor correction converter (PFC) developed with a new active snubber circuit. The soft switched boost power factor correction converter has merits of less voltage and current stresses, improved efficiency and reduced switching losses. Thus the cost and complexity of the converter is reduced. The dual mode controller combines both continuous conduction mode (CCM) and critical conduction mode (CRM). The simulation results declare high efficiency and optimum power factor for wide range of varying loads.

Keywords Power factor correction · Soft switching · Critical conduction

56.1 Introduction

This proposed PFC converter has simple structure, low cost, and easy of control as well. Boost converters operating in continuous conduction mode (CCM) have become particularly popular because reduced electromagnetic interference (EMI)

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C. Kamalakannan et al. (eds.), *Power Electronics and Renewable Energy Systems*, Lecture Notes in Electrical Engineering 326, DOI 10.1007/978-81-322-2119-7_56

levels result from its utilization. Within this context, this work deals with a comprehensive review of some of the most relevant ac-dc single phase boost converters for PFC applications [1, 2]. The cause of having low PF and high THD for a diode-capacitor type of rectifiers is related to nonlinearity of the input current. Method of re-shaping the input current waveform to be similar pattern as the sinusoidal input voltage is done by the Boost converter and the related controls that act as a Power Factor Correction (PFC) circuit [3]. The results of the designed system were compared against with and without PFC control.

56.2 Soft Switching Power Factor Correction Converters

56.2.1 Operation Stages and Analysis

The proposed circuit diagram for PFC converter is shown in Fig. 56.1. In this circuit, V_i is input ac voltage, V_o is output L_F is source inductance, output capacitor C_o act as a filter circuit and resistance R act as Load, the two switches S_1 and S_2 are main and auxiliary switches respectively, and D_F is the main diode. The main switch consists of a main switch S_1 and its body diode D_{S1}. C_S is the sum of the parasitic capacitors of the main switch. L_{R1} and L_{R2} are upper and lower snubber inductances, C_R is snubber capacitor. The diodes D_1, D_2, D_3, and D_4 are act as an auxiliary diodes. L_m is the magnetization inductance, the transformer has a leakage inductances of L_{il} and L_{ol} respectively [4]. In Fig. 56.1 i_s is input current, I_i is

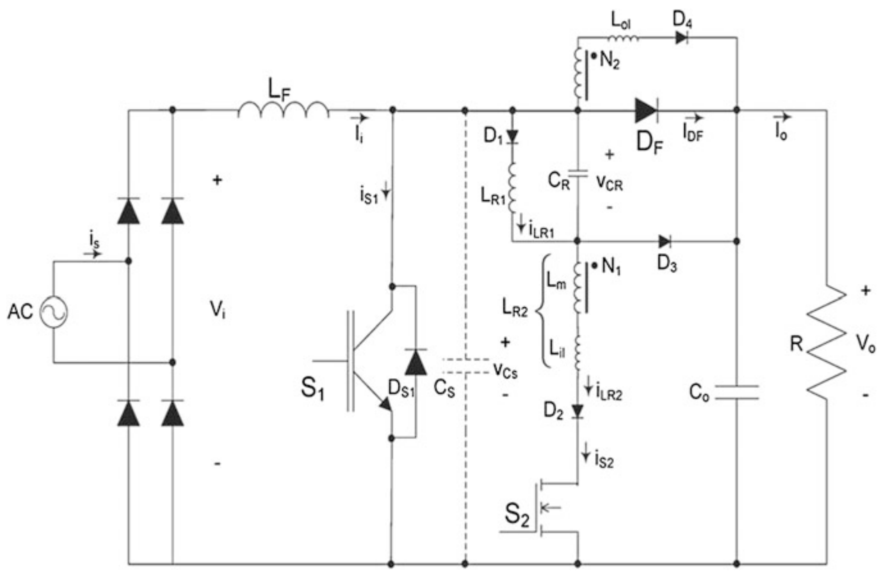

Fig. 56.1 Circuit scheme of the proposed new power factor converter

current flowing through main inductance and i_{S1} is current in main switch, i_{LR1} is L_{R1} inductance current, i_{LR2} is L_{R2} inductance current, i_{S2} is current in auxiliary switch, i_{DF} is main diode current, and I_o is output current. V_{CS} and V_{CR} are voltage across capacitance C_S and C_R respectively.

For one switching cycle, the following assumptions are made in order to simplify the steady-state analysis of the circuit shown in Fig. 56.1. Output voltage V_o and input current I_i are constant for one switching cycle, and all semiconductor devices and resonant circuits are ideal [5]. Furthermore, the reverse recovery times of all diodes are not taken into account (Fig. 56.2).

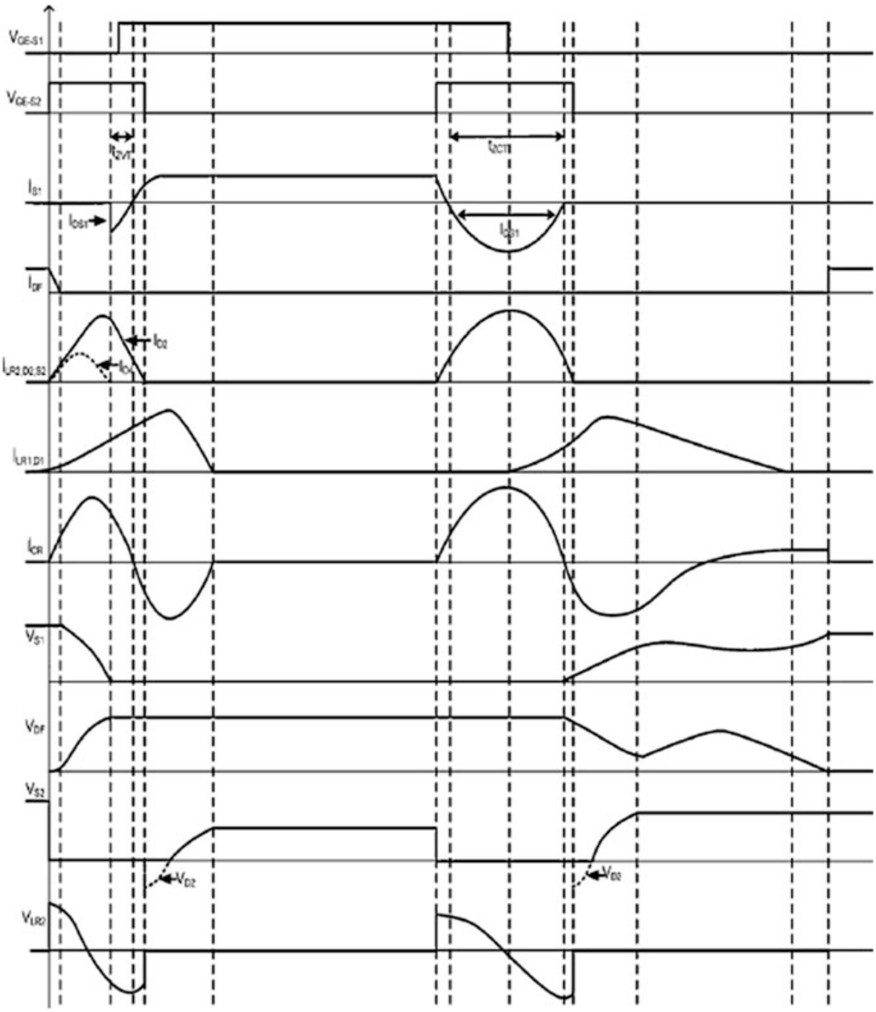

Fig. 56.2 Key waveforms concerning the operation stages in the proposed converter

56.3 Converter Features

The proposed PFC converter is equipped with ZVT–ZCT–PWM active snubber circuit to combine most of the desirable features of both the ZVT and ZCT converters [4]. The proposed converter overcomes most of the drawbacks of these converters and also provides PFC.

- All semiconductors work with SS in the proposed converter. The main switch is turned ON with ZVT and is turned OFF with ZCT, the auxiliary switch is turned ON and OFF with ZCS. Other components of the converter also work with SS.
- There is no extra current or voltage stress on the main switch.
- There is no extra current or voltage stress on the main diode.
- The circulating energy is quite small in this converter and the sum of the transient time intervals is very small for part of the one switching period.
- Due to the main and the auxiliary switches have a common ground, the converter can easily control.
- The proposed new active snubber circuit can be easily applied to the other basic PWM converters and to all switching converters.
- The new presented active snubber circuit can be adapted to the other dc–dc converters.
- At light-load conditions, in the ZVT process, the main switch voltage falls to zero earlier due to decreased interval time t_{01} and that does not make a problem in the ZVT process for the main switch.
- At light-load conditions, in the ZCT process, the main switch's body diode ON-state time is increased when the input current is decreased. However, there is no effect on the main switch turn-OFF process with ZCT.
- Reverse recovery problems of the main and the auxiliary diodes are prevented by using silicone carbide (SIC) diodes in the proposed PFC converter.

56.4 Soft Switching Conditions

In order to achieve SS for the main and the auxiliary switches, the following conditions should be satisfied in the Circuit.

56.4.1 Main Switch Turn ON with ZVT

While the main switch is in OFF state, the control signals applied to the auxiliary switch. The parasitic capacitor of the main switch should be discharged completely and the main switch's anti parallel diode should be turned ON [6]. The ON-state time of the ant parallel diode is called t_{ZVT} and in this time period, the gate signal of the main switch should be applied. So, the main switch is turned ON under ZVS and ZCS with ZVT.

56.4.2 Main Switch Turn OFF with ZCT

While the main switch is in ON state and conducts input current, the control signal of the auxiliary switch is applied. When the resonant starts, the resonant current should be higher than the input current to turn ON anti parallel diode of the main switch. The ON-state time of the anti parallel diode (t_{ZCT}), has to be longer than the main switch's fall time ($t_f s_1$) [7]. After all these terms are completed, while anti parallel diode is in ON state, the gate signal of the main switch should be cutoff to provide ZCT for the main switch.

56.4.3 Auxiliary Switch Turn ON with ZCS

The auxiliary switch is turned ON with ZCS because the coupling inductance limits the current rise speed. The current pass-through the coupling inductance, should be limited to conduct maximum input current at the end of the auxiliary switch rise time ($t_r s_2$). So, the turn-ON process of the auxiliary switch with ZCS is provided.

56.4.4 Auxiliary Switch Turn OFF with ZCS

To turn OFF the auxiliary switch with ZCS, while the auxiliary switch is in ON state, the current pass through the switch should fall to zero with a new resonant. Then, the control signal could be cutoff. If C_S is neglected, $\mathrm{L_{R1}}$ value should be two times more than $\mathrm{L_{R2}}$ to fall the auxiliary switch current to zero. Because the current cannot stay at zero as long as the auxiliary switch fall time (t_{fs2}), the auxiliary switch is turned OFF nearly with ZCS.

56.5 Simulation Results

See (Figs. 56.3, 56.4, 56.5, 56.6 and 56.7).

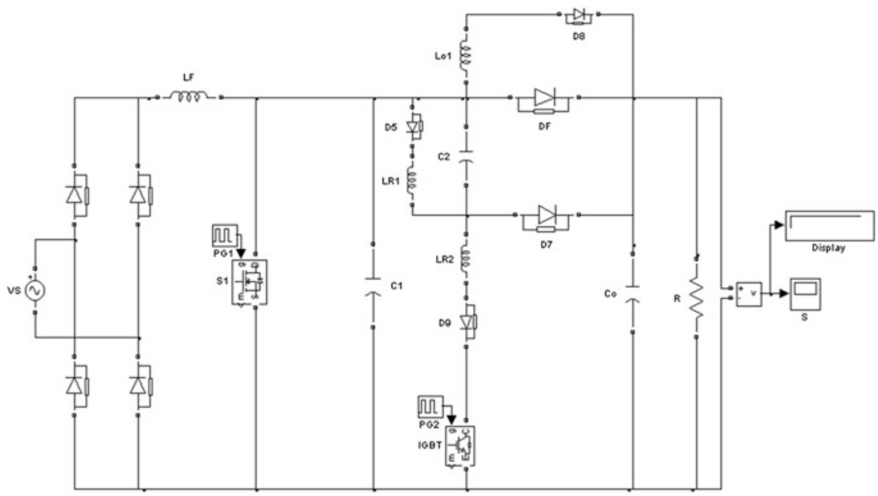

Fig. 56.3 Open loop circuit diagram

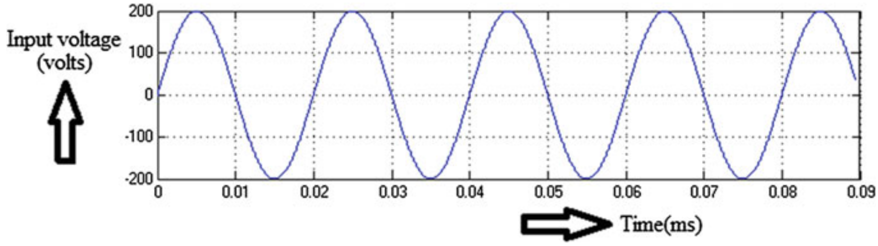

Fig. 56.4 Input voltage waveform

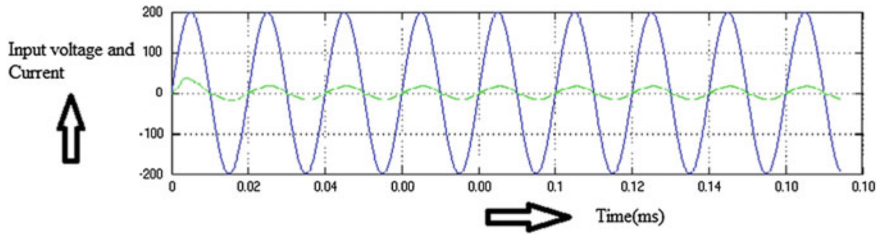

Fig. 56.5 Input voltage and current waveforms

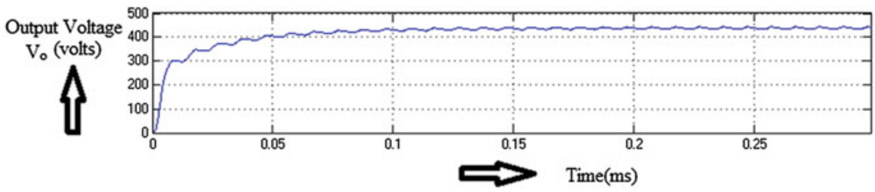

Fig. 56.6 Gate and drain for source voltage waveform

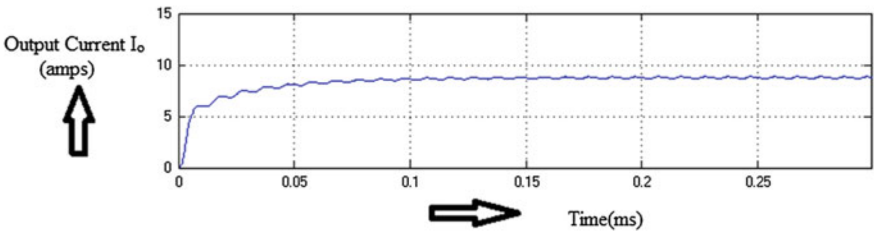

Fig. 56.7 Output current waveform

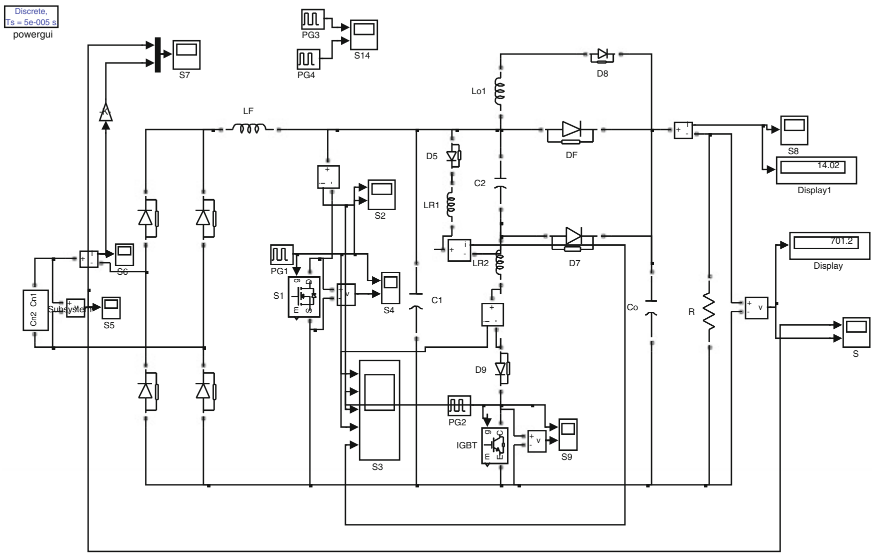

Fig. 56.8 Circuit diagram with disturbance

56.5.1 Circuit Diagram with Disturbance

See (Figs. 56.8, 56.9, and 56.10).

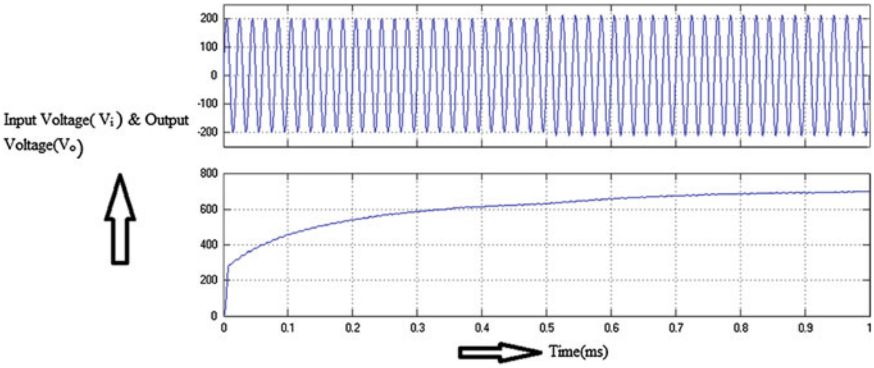

Fig. 56.9 Input and output voltage

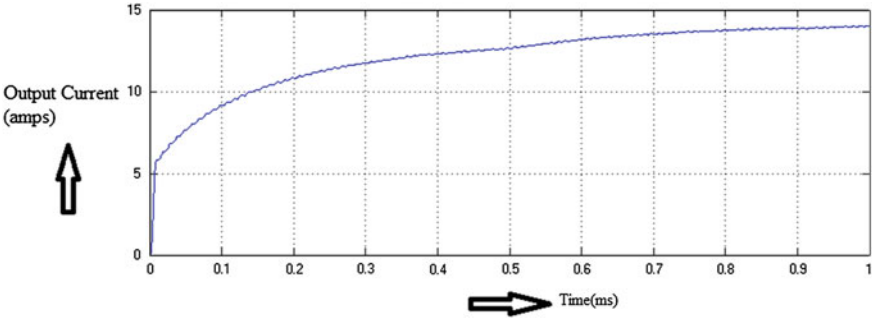

Fig. 56.10 Output current

56.6 Conclusions

In this paper a new power factor correction technique is proposed. The main switch and other semiconductor devices are operated by using ZVT and ZCT methods. The main switch is turned ON with ZVT and turned OFF with ZCT, the auxiliary switch is turned ON and turned OFF with ZCS. A part of the current on the auxiliary switch is transferred to the output load by the coupling inductance to improve the efficiency of the converter. The diode is added serially to the auxiliary switch path to prevent the incoming current stresses from the resonant circuit to the main switch. There are absolutely no current or voltage stresses on the main switch and auxiliary switches.

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