A Study on Bidirectional Boost-Buck Chopper Type AC Voltage Regulator

Isnanto, Woo-Seok Choi, Sung-Jun Park
Chonnam National University

이스난도, 최우석, 박성준
전남대학교

Abstract

The bidirectional boost-buck chopper type AC voltage regulator is presented in this paper. The main characteristic of the AC chopper is the fact that it generates an output AC voltage larger or lower than the input AC one, depending of the instantaneous duty-cycle. Boost-buck chopper type AC voltage regulator, derived from the DC chopper modulated method, is a kind of direct AC-AC voltage converter and has many advantages: such as fast response speed, low harmonics and high power factor. It adopts high switching frequency AC chopper technique and can do wide range step less AC voltage regulation.

Keywords: AC Chopper, AC/AC converter, bidirectional AC voltage regulator.

1. Introduction

In a large number of industrial applications, it is required to convert AC voltage to a different AC voltage level, called AC voltage regulation. There are some types of AC /AC converter to regulate the input voltage to a lower or higher output voltage. A winding transformer is widely used in voltage regulation fields such as power system, motor speed control and so on. However, because the winding ratio is changed by servo motor or by manual regulation, it has low regulation speed. There are also other researches which use thyristor phase controlled circuit to do voltage regulation. These converters have been widely used as a soft-starter and a speed regulator of pumps and fans. Although it has a higher regulating speed than winding transformer, the low input power factor and the large amount of the low-order harmonic current are the major problems.

These problems can be solved by using AC chopper base on the pulse width modulation (PWM) switching. The input voltage is chopped into segments and the output voltage is regulated by changing the duty ratio of the control signal. The advantages are nearly sinusoidal input-output currents/voltage waveforms, improved power factor, reduced harmonic current, a fast response speed and a smaller input filter size. It can protect sensitive tools such as a computer or communication equipment, it can also be used to solve power quality problems caused by line voltage sags and swells.

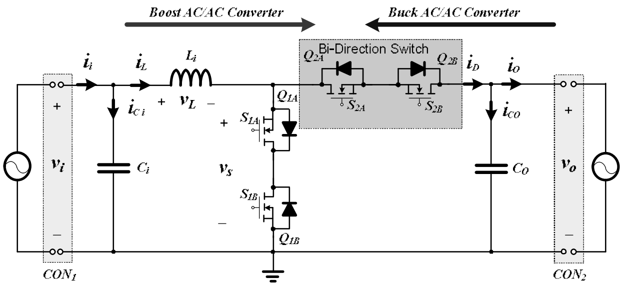

Fig. 1 Circuit topology of the proposed bidirectional boost-buck chopper type AC voltage regulator

2. The Proposed Boost-Buck AC Chopper

The proposed of bidirectional boost-buck chopper type AC voltage regulator is shown in fig. 1. This circuit topology has the succeeding attributes: it can be operate as boost AC/AC converter (forward) and buck AC/AC converter (backward), determine by the direction of view. The input filter consisting of inductor L_i and capacitor C_i, absorbs the harmonic currents. There are also four switching devices (MOSFET) S_{1A}, S_{1B}, S_{2A} and S_{2B} to warranty the power will flow in proper. MOSFET has the inner anti-parallel diode which provide freewheeling currents path when the reserve voltage is encountered. The inductor L is used to store and transfer the energy to the output side. The output filter capacitor C_o reduces the output voltage ripple.

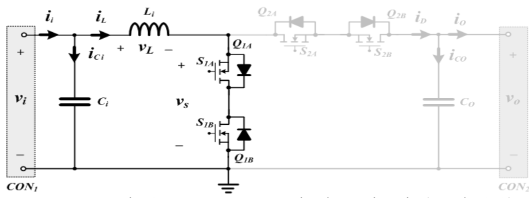

Fig 2. Boost type equivalent circuit (mode 0,2)

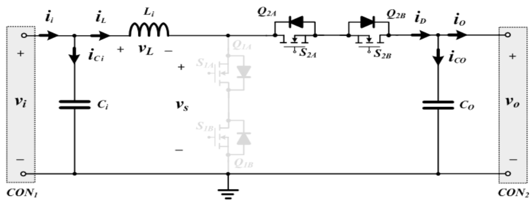

Fig. 3 Boost type equivalent circuit (mode 1,3)

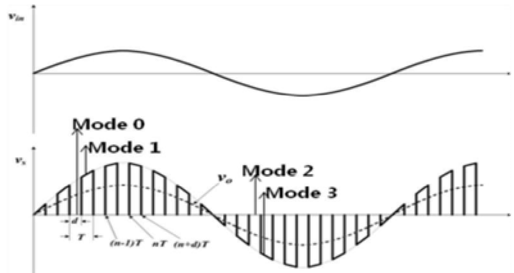

Fig. 4 Generating PWM on boost type

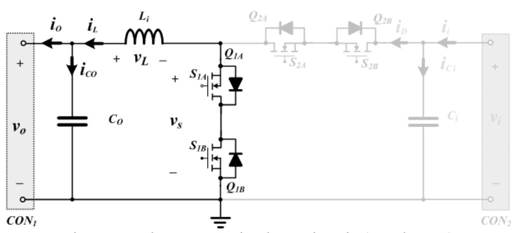

Fig. 5 Buck type equivalent circuit (mode 0,2)

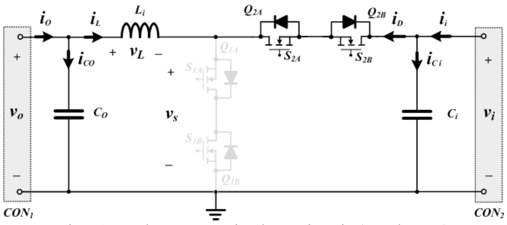

Fig. 6 Buck type equivalent circuit (mode 1,3)

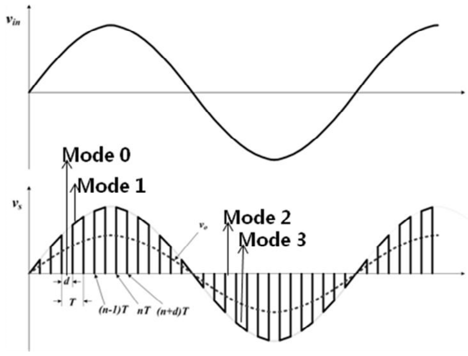

Fig.7 Generating PWM on buck type

Both converters have the same control, depending on the voltage source Vi sign. In this way, if Vi is positif , S_{1A} and S_{1B} switches are PWM controlled with a constant duty ratio (D), while S_{2A} and S_{2B} are fully turn off. When the sign of the voltage source is changed, the switching pattern is reversed, S_{2A} and S_{2B} being complementary PWM controlled with a constant duty ratio, and S_{1A} and S_{1B} are fully turn off. In these switching patterns, the current path always exits whatever the inductor current direction. In the boost converter topology, the output voltage can be determined by:

$$Vo = Vin / (1-D) \quad (1)$$

While in buck converter topology, the output voltage is proportional with the duty ratio:

$$Vo = Vi * D \quad (2)$$

Every cycle of input voltage (phase positive and negatif), both of topology circuit (boost and buck) has four mode operations base on the PWM switching that is applied. Mode 0 and 2 are representative for time OFF of the PWM switching, while the time ON of the PWM switching is referred to mode 1 and 3.

3. Simulation Results

To verify the proposed method, simulations are conducted in PSIM. All of the simulation used the parameter: duty ratio (D) = 0,5 and frequency switching (Fs) 20kHz.

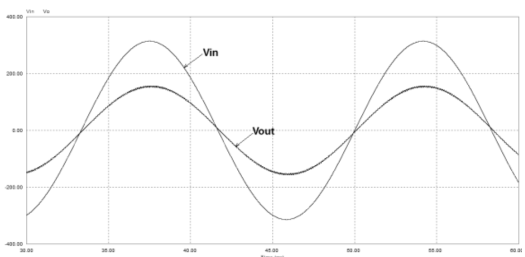

Fig. 8 Buck AC/AC converter Vi vs Vo

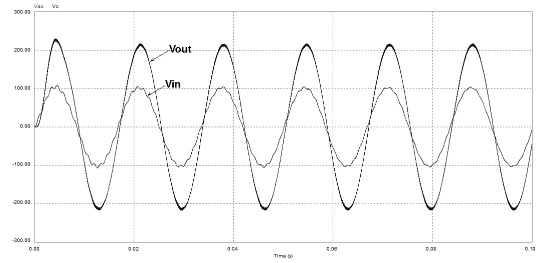

Fig. 9 Boost AC/AC converter Vi vs Vo

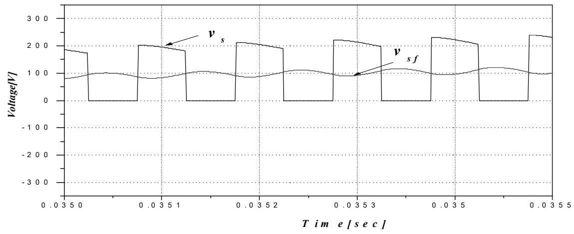

Fig. 10 Voltage switching (Vs) vs voltage switching filter (Vsf)

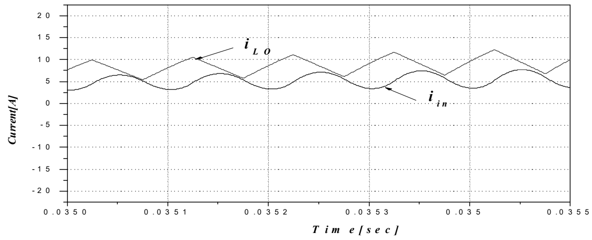

Fig. 11 Input current (i_{in}) vs inductor current (i_{LO})

4. Conclusions

The bidirectional boost-buck chopper type AC voltage regulator has many advantages compared to winding transformer and thyristor phase controlled voltage regulator. The simulation results show that the voltage controller has a good dynamic performance when input voltage swells or sags occur. The boost-buck chopper type AC voltage regulator can improve the power factor and reduce the power loss caused by the reactive and harmonic currents. In addition, it has significant meaning in protecting the voltage sensitive load against the line voltage swells and wags.

Reference

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