ANALYSIS OF PWM CONTROLLED BUCK-BOOST AC VOLTAGE REGULATOR WITH MITIGATION OF VOLTAGE SAGS AND SWELLS

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ABSTRACT

Thyristor based controlled method in AC voltage regulator has very low dynamic response and discharge large amount of harmonic components. And a PWM Controlled Buck-Boost AC Voltage Regulator can efficiently and economically used in low and medium power applications in the advantage of design simplicity with operation reliability in a clear withstand of naturally commutated schemes. It has very fast response speed, low harmonics component distortion and high power factor. In this paper we propose a voltage controller with output peak voltage and reference as feedback signal and adopts conventional control strategy to regulate the output voltage. The experimental results of PWM Controlled Buck-Boost AC Voltage Regulator is presented using MATLAB software.

Keywords: Boost Converter, AC Voltage Regulator, PID Controller, Pulse Width Modulation, Potential Transformer.

I INTRODUCTION

AC voltage regulation is the important part of power conversion methods. There are some types of AC/AC converter which regulate the input voltage and input current to a lower or higher output voltage. An ideal transformer is widely used in the voltage regulation control fields such as power system, motor speed control and so on. The winding ratio is changed by the servo motor or by manual regulation, and it has very low regulation speed. There are also some other researches which use thyristor phase controlled circuit for voltage regulation. These converters have been used as a soft starter and a speed regulator of pumps and fans. Even though 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. The size of the passive filter becomes larger.

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 equipment such as a computer or communication equipment; it can also be used to solve power quality problems caused by line voltage sags and swells. In order to reduce the power loss, researches have been conducted to reduce the number of the switching devices. Three switches and four switches AC chopper were discussed in previously presented papers. Different working

Principles have also been presented to ensure the safety of the converter. The switching patterns are critical and an alternate path has to be established in dead time. DC regenerative snubber capacitor is used to realize the safe commutation and enhance efficiency. Although there are various researches that focus on the topology of the AC chopper converter, little attention has been given to the theoretical analysis of the input power factor. In addition, because most of the previous proposed control methods are open loop control, voltage regulation performance is restrained.

II CIRCUIT CONFIGURATION

The proposed circuit has the following characteristic: it can operate directly from the single-phase line and regulate the output voltage higher or lower steplessly. Furthermore, the input voltage phase synchronous circuit is unnecessary in this scheme. As a result, the circuit is simplified and the cost is reduced. The input filter, consisting of inductor L and capacitor C, absorbs the harmonic currents. The switches S1 and S2 are bi-directional. The used bi-directional switch module is composed of two insulated gate bipolar transistors IGBT. This bi-directional switch structure make the two IGBT share the common the driver circuit, thus the circuit hardware design is simplified. The used IGBT has inner anti-parallel diode which provide. Freewheeling currents path when the reverse voltage is encountered. The inductor L is used to store and transfer the energy to the output side. The switch S1 is used periodically to connect and disconnect the inductor L to the supply, i.e., it regulates the power delivered to the inductor The switch S provides a freewheeling path for the inductor current to discharge the stored energy of the inductance L when the switch turned off. These switches are control PWM signals with constant duty ratio. R1 , R2 are the snubber capacitors and resistors respectively. The snubber circuits are connected in parallel with the bi-directional switches. The output filter capacitor reduces the output voltage ripple to the supply, i.e., it regulates the power delivered to the inductor L. provides a freewheeling path for the inductor current to discharge the stored energy of the inductance L when the switch S is turned off. These switches are controlled by PWM signals with constant duty ratio. C and are the snubber capacitors and resistors respectively. The snubber circuits are connected directional switches. The output filter capacitor reduces the output voltage ripple.

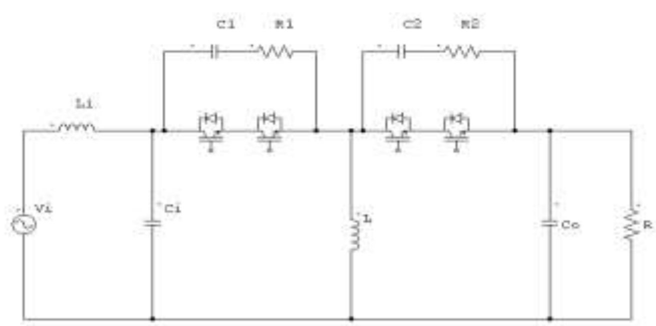

Fig. 1. Buck Boost AC Voltage Regulator.

In the switching period, the input voltage ui and the output voltage uo are considered to be constant. When ui>0, the waveforms of inductor voltage ul and current il. The inductor voltage ul is ui during the active mode or uo during the freewheeling mode.

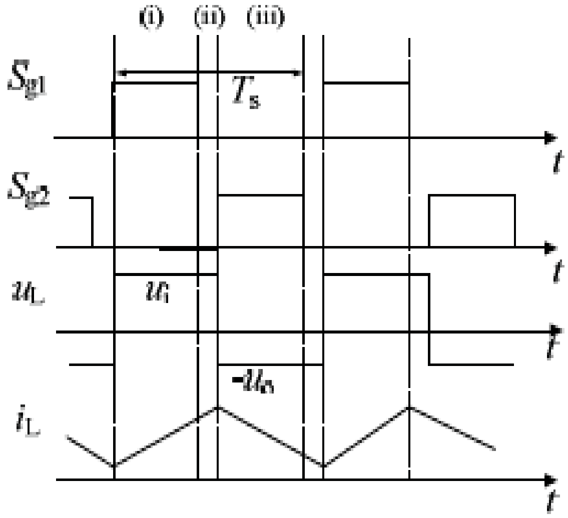

Fig 2: Wave Forms of the Inductor Voltage and Current

In ideal condition, the inductor voltage of ul can be expressed as follws:

$$u_L(t)=Du_i(t)-(1-D)u_o(t)$$

Where ui(t) and uo(t) are the average AC input voltage and output voltage during the switching period, respectively, and D is the duty ratio. Because the switching frequency is much higher than the line frequency.

$$i_i(t)=Di_L$$

$$i_o(t)=(1-D)i_L(t)$$

Where il(t) is the average inductor current the switching period. The inductor current produces the output current during the freewheeling mode, and the inductor current is caused by the input current during the active mode.
The PID controller is used as which the derivative part is also included along with the integral part since the gain values increases when PID is considered rather than the PI controller.

III SIMULATION RESULTS

To show the feasibility of the proposed analysis method and control strategy, the simulation model of the proposed voltage regulator is setup using PSIM software. The simulation is constructed based on the figure as shown below.

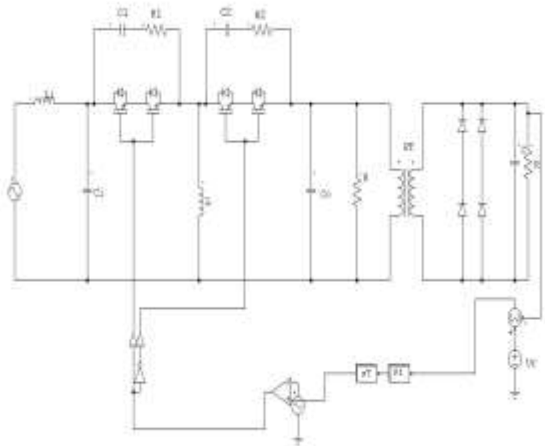

Fig 3: PWM Controlled Buck Boost AC Voltage Regulator

According to the diagram, the simulation results are consistent with the theoretical analysis. The chopper type AC voltage regulator has a high input power factor and can reach the unit power factor in working zone.

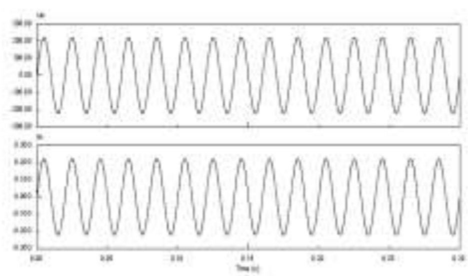

Fig 4: The input voltage and current waveforms PWM controlled Buck-Boost AC voltage regulator

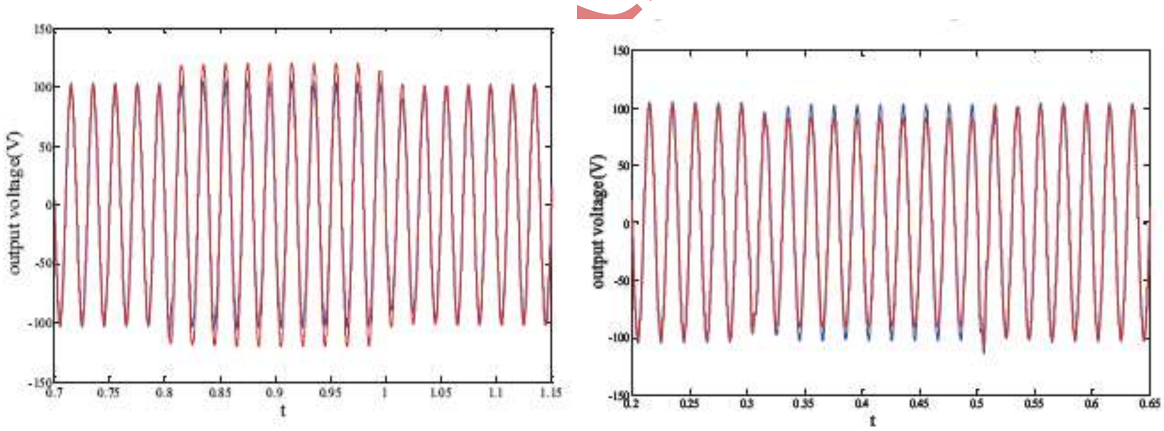

Fig. 10. (a)Waveforms of output voltage voltage sags of 20% in the input voltage (b) voltage swells of 20% in the input voltage

IV CONCLUSION

The PWM Controlled Buck-Boost AC Voltage Regulator has many advantages compared to the thyristor phase controlled voltage regulator. The analysis method of the input power factor is presented. Compared with other voltage regulator, the input current is in a sinusoidal waveform with less harmonic components. The output voltage control system is designed using PID control method and the peak-voltage detector. The simulation results show that the voltage controller has a good dynamic performance when input voltage swells or sags occur. The PWM Controlled Buck-Boost 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 sags.

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