International Journal of Internet, Broadcasting and Communication Vol.5 No.1 6-8 (2013)
http://dx.doi.org/10.7236/IJIBC.2013.5.1.6

IJIBC 13-1-2

AC TO AC Direct Voltage Conversion Using A Solid State Transformer

Keehong Um[1]

[1]*Department of Information Technology, Hansei University, Korea*
um@hansei.ac.kr

Abstract

In this paper, we present an intelligent digital controller circuit which can be applied to automatic voltage regulation. The proposed solid state transformer with Pspice simulation model shows that our approach is very efficient and produces the desirable output. It is comparable to an ordinary magnetic coupled autotransformer.

Keywords: *switched-mode power supply (SMPS), Buck converter, duty cycle*

1. Introduction

A switched-mode power supply (SMPS): the Buck converter or the boost converter is an electronic power supply unit that incorporates a switching regulator [1]. The input and output voltage ratio of SMPS mainly depends on the duty cycle of switches in the circuit. The resulting rectangular waveform is low-pass filtered with an inductor and a capacitor. The capacitors in the circuit reduce the radio frequency (RF) noise. Other advantages include smaller size and lighter weight (from the elimination of low frequency transformers which have a higher weight) and lower heat generation due to higher efficiency [2]. The Buck converter (or the boost converter) which has bi-directional switching devices, can be used to make a solid stage transformer. The input and output voltage ratio of buck converter mainly depends on the duty cycle of switches in the circuit.

2. Structure and Operation

2.1 Solid state transformer

An example of simplified structure of a solid state transformer is illustrated in Fig. 1. The duty cycle *D* of the circuit can control the output voltage. The circuit is a Buck converter which converts high input voltage to low output voltage with active switch devices S1 and S2. For example, we may use this converter for input voltage to low output voltage purposes or vice versa. This operation makes SMPS similar to the autotransformer's operation: a bi-directional operation or four quadrant operation. For a device with low power factor (PF), the solid state transformer works better compared to the DC-linked voltage converter [3]. When the switch S1 is on in Fig.1, the input voltage is applied to the inductor, and during the rest of one cycle, S1 is on to make inductor voltage 0 volt. Therefore, the average voltage across the inductor is equal to input voltage times the duty cycle D. The inductor of Fig.1 should be chosen properly considering the input frequency and switching speed of S1 and S2. Thus, the output voltage of the converter is proportional to the input voltage times the duty cycle D, which is not used for DC-operated converters. For example, if D = 0.5, the amplitude of output voltage is equal to 50 % of input voltage amplitude. To convert the voltage level

Manuscript Received: Nov. 28, 2012 / Revised: Jan. 10, 2013 / Accepted: Feb. 8, 2013
[1]Corresponding Author: um@hansei.ac.kr
Tel:+82-31-450-5308,Fax: +82-31-450-5172,
Dept. of Information Technology, Hansei University, Korea

from high to low, a Buck converter can be used.

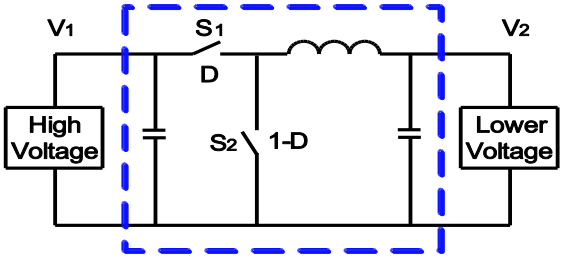

Figure 1. Simplified schematic of a solid state transformer

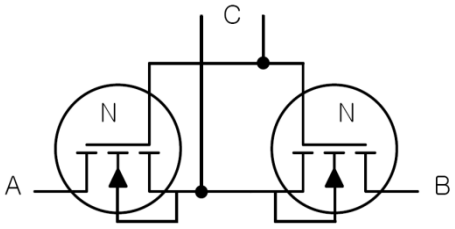

Figure 2. An example of a bi-directional solid state switch

2.2 Bi-directional solid state switches

Fig. 2 shows typical bi-directional solid state switches which are connected back to back and can be used for the switches S1 and S2 in Fig.1. Those bi-directional switches can control terminal voltage and current by adjusting on-off control signals applied at port C. We can design various kinds of bi-directional solid switches using MOSFET, BJT, Diode, or IGBT(Insulated Gate Bipolar Transistor). In Fig. 2, two transistors connected in series operate as a bipolar voltage and bi-directional current switch. When the gate voltage is sufficiently higher than the source voltage, the two transistors flow the current in the direction of the drain to the source or vice versa.

3. Measured Results

The proposed converter needs an intelligent digital controller circuit, and can be applied to operate an automatic voltage regulation function, which is better than an ordinary magnetic coupled autotransformer. In this configuration, the perturbed input voltage is regulated for stable low side output voltage by changing the duty cycle of the circuit. The proposed solid state transformer with Pspice simulation model [4] illustrated in Fig. 3 shows that it converts the $220V_{rms}$ input AC voltage to $110V_{rms}$output AC voltage isshown in Fig.4

4. Conclusion

Up to now, switched-mode power supply (SMPS) has been used only to generate DC power. We applied the semi-conductors to transform AC voltage to AC voltage directly. Since the voltage is transformed without using the DC-link, the properties are the same as those of an autotransformer.

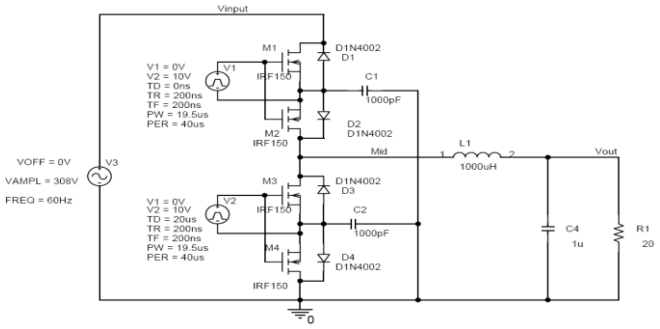

Figure 3. Pspice simulation model

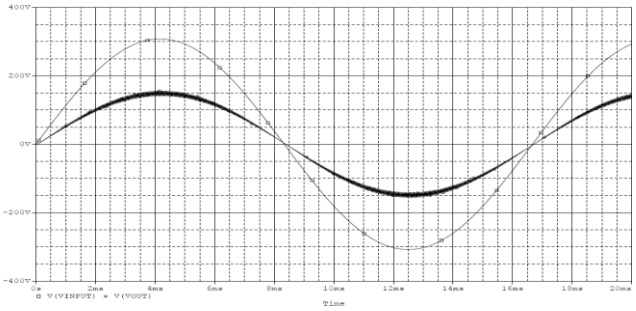

Figure 4. Pspice simulation result

Acknowledgement

This work was supported by Hansei University.

References

[1] A. Pressman, Switching Power Supply Design, 2nd ed. McGraw-Hill, 1997.
[2] SWITCHMODE Power Supplies – Reference Manual and Design Guide, OM Semiconductor, 2007.
[3] E. da Silva, M. Cavalcanti, C. Jacobina, “Comparative study of pulsed DC-link voltage converters”, EEETransactionsonPowerElectronics,vol.18,no.4,July2003,pp.1028-1033.
[4] C. Basso, Switch-Mode Power Supplies Spice Simulations and Practical Designs, McGraw-Hill, 2008.