3상 변압기를 이용한 고밀도 양방향 전력변환기

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Three-Phase High-Power-Density Bidirectional DC-DC Converter

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ABSTRACT

This paper presents a three phase high power density bidirectional DC DC converter. The converter employs dual three phase active bridges and a three phase transformer. The presented converter is controlled by two symmetric PWM modules and phase between two symmetric PWM modules to control the power flow. Simulation is included to verify the presented converter.

1. Introduction

Three phase systems are well known by their use in electric power generation transmission and distribution. The cost saving that they provide by employing less material than single phase systems assured success in these areas and led to three phase rectifiers, inverters, and also dc dc converters.

In high power applications such as distributed generation and uninterruptible power suppliers generally count on single phase dc dc converters with big and heavy transformers. The introduction of high frequency three phase transformers on dc dc converters brought the possibility of increasing power density, using the magnetic cores more efficiently and reducing the current stress on power switches. In addition, the increase in the high frequency component seen by the filters allowed the use of much smaller inductors and capacitors.

In this paper, a three phase high power density bidirectional dc dc converter is studied. In this converter, the use of a three phase transformer instead of single phase transformers to increasing the power density with all good performance in high power applications of the three phase converter. The topology, modulation method and simulation result is presented in this paper.

2. Contents

2.1 Decription of the converter

The converter consists of dual three phase active bridges and a three phase high frequency transformer in a Y/Y connection, as shown in Fig.1. The transformer provide the required galvanic isolation and voltage level matching between the low voltage bus and high voltage bus with a turns ratio of 1:N between the primary and secondary winding. The leakage inductances of the transformer are utilized as the intermediate energy storing and transferring elements. The snubber capacitors across each switch, including the parasitic capacitance of the switches, resonate with the associated transformer leakage inductance during the dead time between the turn off of one switch and the turn on of the other one in the same switch leg to provide zero voltage turn off and zero current turn on for the respective switch.

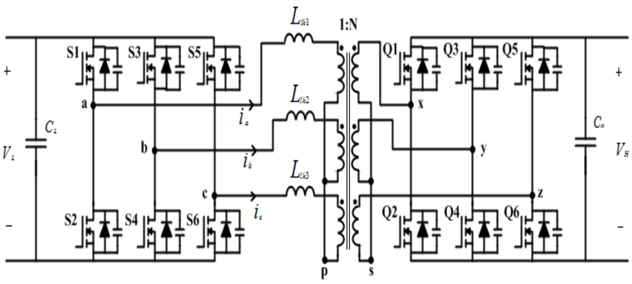

Figure 1. A three phase high power density bidirectional dc dc converter.

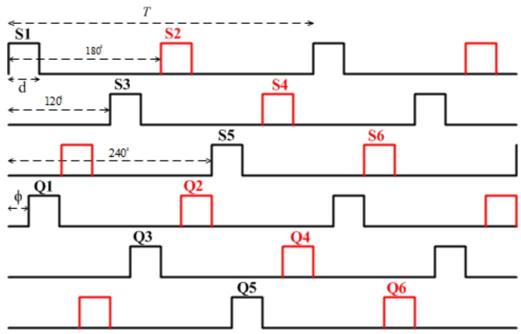

Figure 2. PWM method.

Fig.2 shows the method to generate PWM signal for dual bridge switches. Dead zone time between the top and bottom switches in the same leg is required for the time resonance of the snubber capacitors and the transformer leakage inductance.

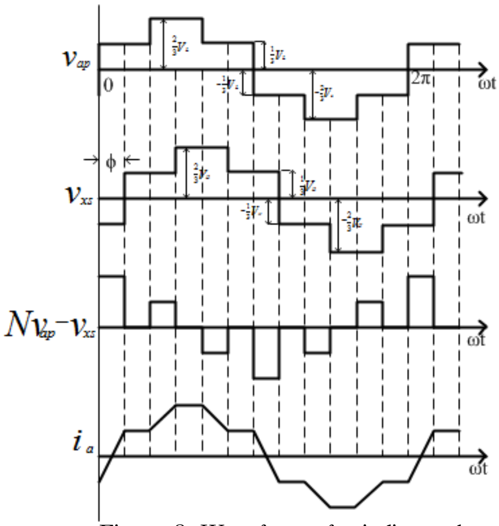

Figure 3. Waveform of winding voltages and current when phase is different.

From the Fig.3, the direction of power flow is determined by the phase angle between the low voltage switches and high voltage switches. Because of the angle, the power can be transfer between the two sides. We define that when the low voltage side leads the high voltage side, the angle is positive while the angle is negative when the low voltage side lags the high voltage side. The power transfer direction is decided by the sign of the phase shift angle and the value of transferred power is decided by the value of the angle.

The transferred power is calculated by the following equation [1] :

$$P_o = \frac{V_L V_H}{\omega L_{lk}} \phi \left(\frac{2}{3} - \frac{\phi}{2\pi} \right) \qquad 0 \le \phi \le \frac{\pi}{3}$$

$$P_o = \frac{V_L V_H}{\omega L_{lk}} \left(\phi - \frac{\phi^2}{\pi} - \frac{\pi}{18} \right) \qquad \frac{\pi}{3} \le \phi \le \frac{2\pi}{3}$$

$$P_o = \frac{V_L V_H}{\omega L_{lk}} \left(\frac{\phi}{3} - \frac{\phi^2}{2\pi} + \frac{\pi}{6} \right) \qquad \frac{2\pi}{3} \le \phi \le \pi$$

2.2 Simulation

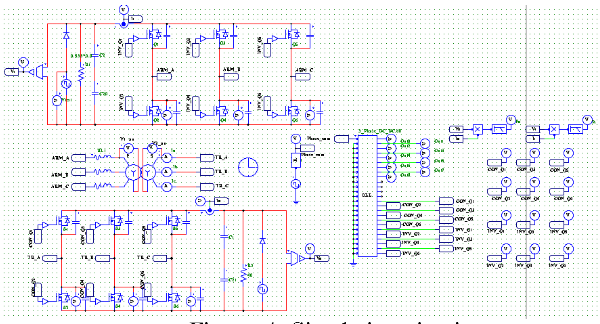

Figure 4. Simulation circuit

Parameter	Symbol	Value	Unit
Output power	Po	4000	W
Low voltage side	VL	40	V
High voltage side	VH	400	V
Switching frequency	fs	10	kHz
Turn ratio	N	10	turn
Leakage inductance	Llk	2	uH
Magnetizing inductance	Lm	150	uH

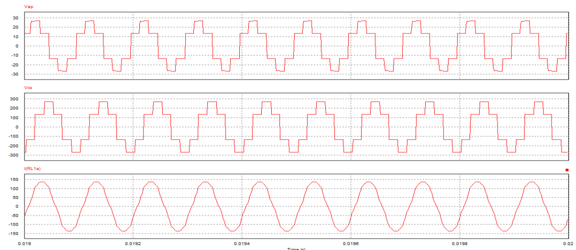

Figure 5. Simulation result of winding voltages and current when the phase is 90^o

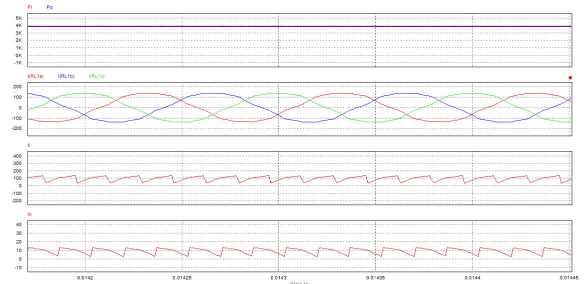

Figure 6. Direction of power flow and waves of currents of boost converter (phase shift angle = 90^o)

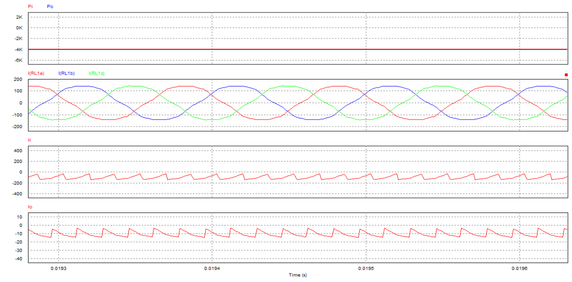

Figure 7. Direction of power flow and waves of currents of buck converter (phase shift angle = -90^o)

3. Conclusion

This paper presented the three phase high power density bidirectional dc dc converter. Simulation was also included to confirm the novel operation and power flow control principle.

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참 고 문 헌

[1] R. De Doncker, D. Divan, and M. Kheraluwala, “A three phase soft switched high power density dc/dc converter for high power applications,” IEEE Trans. Ind. Appl., Vol. 27, No. 1, pp. 63 73, Jan/Feb 1991.