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개선된 Clamp Circuit 적용 ZVZCS FB DC/DC 컨버터

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An Improved ZVZCS PWM FB DC/DC Converter Using the Modified Clamp Circuit

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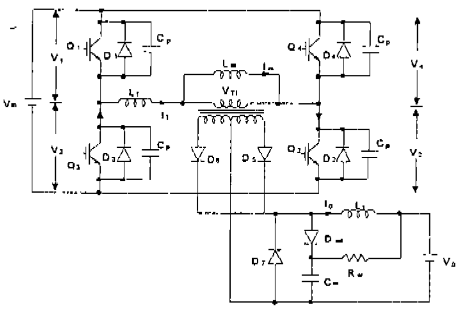
Abstract

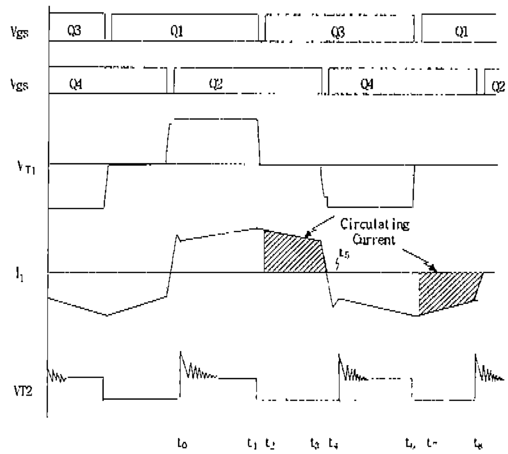
The conventional high frequency phase-shifted full bridge dc/dc converter has a disadvantage that a circulating current flows through transformer and switching devices during the freewheeling interval. Due to this circulating current, RMS current stress, conduction losses of transformer and switching devices are increased. To alleviate this problem, this paper provides a circulating current free type high frequency soft switching phase-shifted full bridge (FB) dc/dc converter with the modified energy recovery snubber (ERS) attached at the secondary side of transformer.

1. Introduction

Recently, many new techniques for high-frequency conversion have been proposed to reduce the component stress of voltage and current, and the switching losses in the traditional pulse-width-modulated (PWM) converter. Among them, the phase-shifted full-bridge (FB) zero-voltage-switched PWM techniques [1] are deemed most desirable for many applications because this topology permits all switching devices to operate under zero-voltage-switching (ZVS) by using the circuit parasitic such as transformer leakage inductance and power device junction capacitance. However, because of phase-shifted PWM control, the converter has a disadvantage that a circulating current which is the sum of the reflected output current (nIo) and transformer primary magnetizing current (Im) flows through the transformer and switching devices during freewheeling intervals.



(a) The conventional full -bridge DC/DC converter



(b) Operation waveforms

Fig. 1 The conventional phase-shifted full-bridge DC-DC converter and its waveforms

Due to the circulating current, RMS current stresses of transformer and switching devices are still high compared with that of the conventional hard- switching PWM full-bridge converter. A lot of the ZVZCS FB DC/DC converter using a simple auxiliary circuit to alleviate these problem have been presented [2, 3, 4]. But, the use of the a simple auxiliary circuit to reduce the circulating current has a lot of disadvantage such like a voltage stress and severe parasitic ringing in the ZVZCS FB DC/DC converters. This paper proposes an improved ZVZCS phase-shifted FB dc/dc converter which applies the modified energy recovery snubber attached at the secondary side of transformer. By using the modified energy recovery snubber, the converter can reduce the circulating current flowing through switching devices during freewheeling intervals and voltage stress in the secondary rectification diodes.

2. The conventional ZVZCS FB DC/DC converters to reduce the circulating current

The families of ZVZCS FB DC/DC converters with auxiliary circuit to reduce the circulating current are reviewed. To facilitate that, the leakage inductance of the transformer to reset the circulating current during freewheeling intervals always need to be kept as low as possible. For their detailed operation principles and problems, the original publications are referred.

2.1 ZVZCS FB DC/DC Converter with a Tapped Filter Inductor [2]

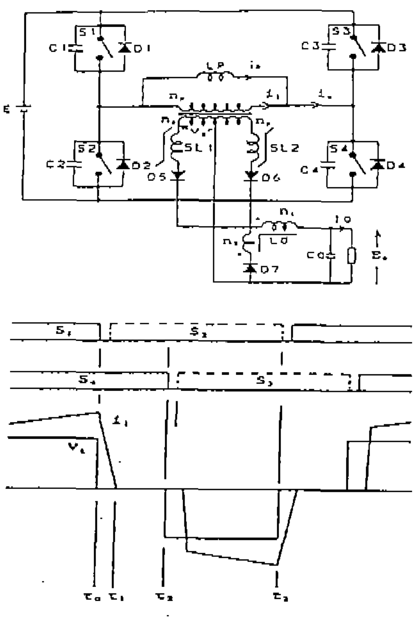


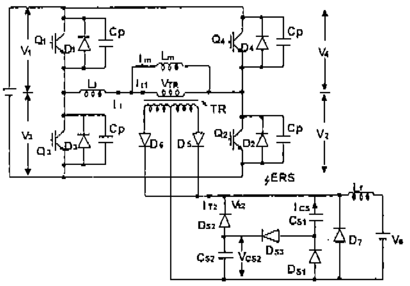
Fig. 2 ZVZCS FB DC/DC converter using a tap inductor

Fig2 shows the ZVZCS FB DC/DC converter which employ a tapped inductor. By using the tapped inductor, the circulating current and conduction losses are substantially reduced. However, Several drawbacks exit for this scheme. As increasing the turns ratio, NL of the tapped inductor to decrease to zero of the circulating current rapidly, voltage stress of D7 and current ripple in the filter inductor Ld, voltage ripple in output capacitor Co is increased. Also, the ZCS capability is limited because the available reset source on the secondary is always a fraction of the output voltage Vo, which is lower than the reflected input voltage. For these reasons, it is suited only for medium power applications.

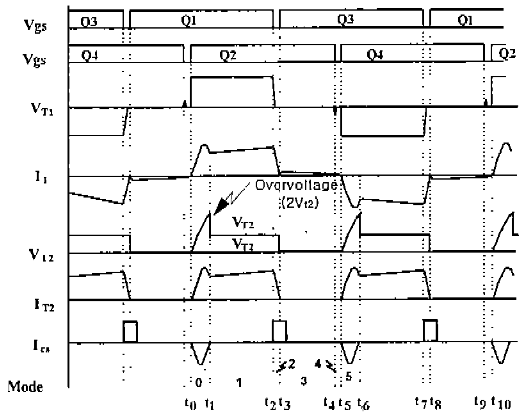
2.2 ZVZCS FB DC/DC converter with an energy recovery snubber [3]

By using an energy recovery snubber instead of adding a tapped inductor and a saturable reactor to reduce RMS current stress such as described in reference[1], the converter can reduce the circulating current flowing during freewheeling intervals. As shown in Fig. 3, the energy stored in the energy recovery snubber capacitor (Cs1, Cs2) during conduction mode(t0-t2, t5-t7) starts discharging when the transformer secondary voltage in the freewheeling intervals becomes zero. Due to the discharging of the snubber capacitor (Cs1,Cs2), the rectifiers D5 and D6 are biased in reverse and the secondary windings of the transformer are opened. Therefore, both primary and secondary currents of the transformer become zero. Thus, the RMS currents for the transformer and switches are considerably reduced in the freewheeling interval (t3-t4, t8-t9). Also, the converter achieves zero voltage switching for secondary rectifiers (D5,D6) and free-wheeling diode(D7) because at the turn-on time of switches (Q1, Q2 and Q3, Q4), the energy recovery snubber provides a low impedance path through transformer, snubber capacitor(Cs1), snubber diode(Ds3) and snubber capacitor (Cs2). However, in this case, during the transition from off stage to active stage (t0-t1), the serial resonance circuit is formed with leakage inductance of transformer and snubber capacitors of secondary, and the secondary current (It1/n) begins to flow to Cs1, Ds3 and Cs2 through the transformer and rectifiers. During the charging process, snubber capacitors are charged up to the two times secondary voltage (2Vt2). As a result, over-voltage on the secondary happens.

Due to the relatively high impedance of the resonant tank, the snubbing or clamping effect for the secondary transient voltage is also lost. Therefor, the modified ZVZCS FB DC/DC converter with clamp circuit is needed to reduce the secondary transient over-voltage.



(a) ZVZCS FB dc/dc converter

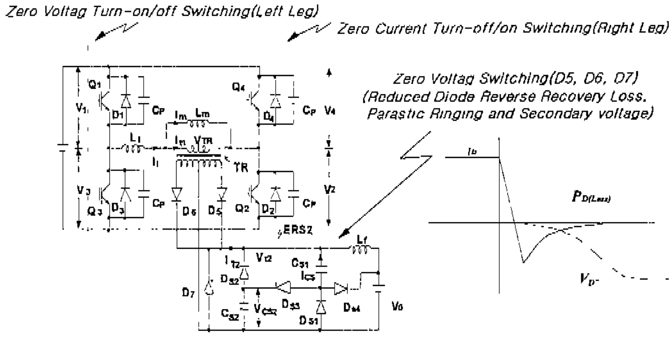


(b) Operation waveforms

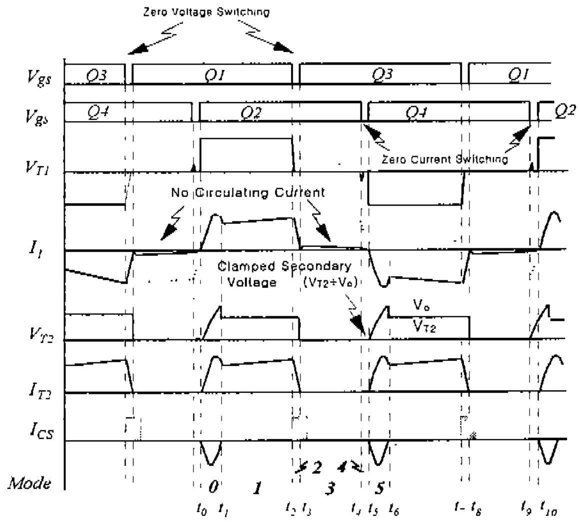
Fig. 3 ZVZCS FB DC/DC converter using energy recovery snubber

2.3 The proposed ZVZCS FB DC - DC Converter using the modified energy recovery snubber

Fig. 4 shows the proposed ZVZCS phase-shifted full bridge dc/dc converter that applies the modified energy recovery snubber to minimize the circulating current and the secondary transient over-voltage. The operating mechanism and circuit configuration of the proposed circuit is similar to the ZVZCS FB dc/dc converter using energy recovery snubber except of inserting the snubber diode (Ds4). The modified energy recovery snubber which is consisted of four fast recovery diodes(Ds1, Ds2, Ds3, Ds4), two resonant capacitors (Cs1, Cs2) is inserted between the transformer secondary side rectifier (D5, D6) and the output inductor (Lf) to reduce the circulating current. The snubber diode Ds4 is connected with the output capacitor (Co) in order that voltage Vcs2 of snubber capacitor is to be clamped from the secondary voltage (Vt2) to the output voltage (Vo). Therefore, the modified ZVZCS FB dc/dc converter can reduce the secondary transient over-voltage as well as the circulating current.



(a) ZVZCS FB dc/dc converter using the modified clamp circuit



(b) Operation waveforms

Fig. 4 The proposed ZVZCS FB DC/DC converter using the modified clamp circuit

References

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