ZVS Bridge Leg and ZCS Bridge Leg DC-DC Converter with Tapped Inductor Filter

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In this paper, a novel full-bridge soft-switching phase-shifted PWM DC-DC power converter circuit is presented. A tapped inductor filter is implemented in the proposed converter topology to achieve soft switching commutation for the active power switches under wide load variation range, to minimize circulating current without using additional resonant circuit and/or auxiliary switching devices. The effectiveness of the proposed soft-switching DC-DC power converter is verified in experiment with 2 kW-100 kHz breadboard circuit using IGBTs.

Keywords: Full-bridge soft-switching DC-DC converter, Phase-shifted PWM, ZVS bridge leg and ZCS bridge leg, Tapped inductor filter, Freewheeling interval.

1. Introduction
In the conventional full bridge (FB) type zero voltage soft-switching (ZVS) phase-shifted pulse width modulation (PS-PWM) DC-DC power converters, a large circulating current flows through the transformer primary side circuit during the freewheeling interval, caused by PS-PWM control strategy\(^{(1)}\). Due to the circulating current, the conduction power losses in the ZVS PS-PWM DC-DC converter arise and the converter efficiency becomes lower compared to the efficiency of the hard-switching FB PWM converter. Moreover, the ZVS commutation for the lagging bridge-leg switches can be achieved only for the very narrow load variation range.

A number of the soft-switching FB type PS-PWM converter circuit topologies with ZVS leading leg and ZCS lagging leg, have been developed\(^{(2)}\). These soft-switching converters can reduce the circulating current and expand soft-switching operation range, but the previously proposed circuits need additional resonant circuits or auxiliary active power switches.

In this paper, a novel FB soft-switching PS-PWM DC-DC power converter circuit with a tapped inductor filter is presented. A tapped inductor is implemented in the output filter stage of the proposed converter to achieve soft switching commutation under wide load variation range, to minimize conduction losses.

2. Circuit Configuration
Fig. 1 shows the proposed circuit configuration of the high frequency transformer linked soft-switching FB type PS-PWM DC-DC power converter. Fig. 2 illustrates switching pulse sequences and theoretical operating waveform of the proposed converter in a steady state. The lossless snubber capacitors C1 and C2 are connected to achieve ZVS commutation of the leading bridge-leg switches S1 and S2. The lagging bridge-leg switches S3 and S4 operates with ZCS at turn on due to the effect of the inductance Ls, which can be substituted by the leakage inductance of the high frequency transformer T. Moreover, the tapped inductor filter L41/L42 is implemented to obtain ZCS for the switches S3 and S4 at turn-off as well as to minimize the circulating current i1 flowing through transformer T primary side components during freewheeling interval t1 (see Fig. 2).

To achieve ZVS commutation for the switches S1 and S2, they are driven complementary with a short blanking interval t4. The output voltage of the proposed converter is regulated by varying interval t_on when the switches S1 and S4 or S2 and S3 simultaneously are conducting (see Fig. 2).

The tapped inductor L41/L42 in the output stage acts in the proposed soft-switching converter as a passive...
clamp component, so that the rectifier stage output voltage \( v_{d} \) is clamped in the positive polarity during the freewheeling interval (see Fig. 2). Therefore, the rectifier diodes \( D_5 \) (or \( D_6 \)) are turned off, and the output inductor current flows through the freewheeling diode \( D_7 \). As a result, the circulating current \( i_1 \) idling through the transformer \( T \) and its primary side circuit during the freewheeling interval \( t_1 \) can be reduced.

3. Experimental Results

To verify the operating principle in a steady state, the experiment is carried out with a 2 kW-100 kHz DC-DC power converter using IGBTs (IRG4PC40UD) under \( E = 360 \) V, \( E_o = 50 \) V, \( I_o = 40 \) A. Fig. 3 illustrates the experimental voltage and current waveforms of the high frequency transformer \( T \) and switches \( S_2 \) and \( S_4 \) under full load condition. Observing the transformer voltage and current experimental waveforms \( v_{ab} \) and \( i_1 \), respectively, it can be concluded the circulating current caused by PS-PWM control scheme is significantly minimized (see Fig. 3(a)). Furthermore, the power IGBTs \( S_2 \) \((S_1)\) operates with ZVS and ZCS at turn-on and with ZVS at turn-off; and the switch \( S_4 \) \((S_3)\) operates with ZCS at turn-on and turn-off (see Fig. 3(b), (c)). The measured actual efficiency of the power DC-DC converter was obtained as 94% over the wide range from 30% to the rated (full) load.

4. Conclusions

The novel FB PS-PWM DC-DC power converter with ZVS and ZCS bridge-legs has been presented in this paper. The conduction losses due to the circulating currents has been reduced with the aid of the tapped inductor in the converter output filter stage. The soft-switching operation over wide load range and PS-PWM regulation has been performed. High efficiency soft-switching operation ability of the proposed power converter has been verified in the experiment using 2 kW-100 kHz IGBTs breadboard circuit.

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References