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# A Novel Active Soft-Switching Converter with loss-less Snubber for MTEM Electromagnetic Transmitter

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## 1. Introduction

Multi-channel transient electromagnetic (MTEM) is an artificial source electromagnetic detection method. The current transmitters have many problems, such as low power density, low efficiency, and narrow dynamic range. These properties cannot meet the actual needs of geological explorations. In this paper, an improved auxiliary circuit for PSFB converter used in MTEM transmitter is proposed, which guarantees the ZVS of the main switches for the entire range of the load. The auxiliary windings ensure the soft-switching of the auxiliary switches, and the cut-off diodes eliminate the current circulation in the auxiliary circuit. Meanwhile, the loss-less snubber in the output rectifier suppresses the voltage ringing. The efficiency of the proposed converter is greatly improved.

## 2. The circuit topology and operation modes

The topology of the improved converter is shown in Fig. 1. And the key waveforms are shown in Fig. 2.

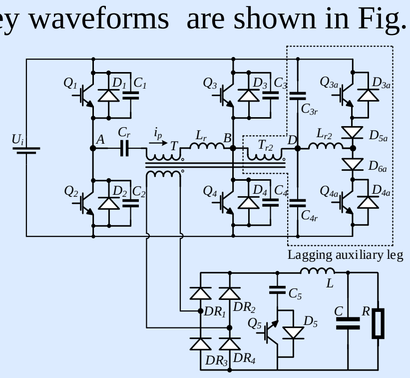


**Figure 1.** Topology of the improved converter.

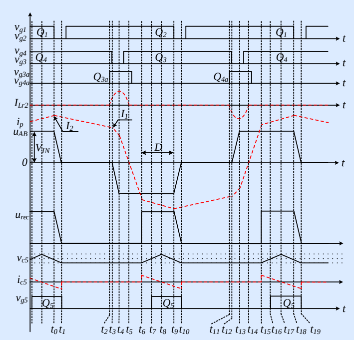

**Figure 2.** Key waveforms of the improved converter

**Mode 1** ($t_0<t<t_1$): The primary current $i_p$ is to charge the resonant capacitor $C_1$ and discharge the capacitor $C_2$.

**Mode 2** ($t_1<t<t_2$): The voltage $u_{AB}$ is zero and the diode $D_2$ is still in the freewheeling state, the current $i_p$ is equal to the reflected filter inductor current $i_L$.

**Mode 3** ($t_2<t<t_3$): The current flows through the devices $Q_{3a}$, $D_{5a}$, $L_{r2}$, $T_{r2}$, and $Q_4$ to charge $L_{r2}$.

**Mode 4** ($t_3<t<t_4$): The current $i_p$ and $i_{Lr2}$ are both used to charge $C_4$ and discharge $C_3$. The voltage of $C_3$ is reduced to zero and the diode $D_3$ is turned on.

**Mode 5** ($t_4<t<t_5$): The current $i_p$ and $i_{Lr2}$ flow through the diode $D_3$ to ensure $Q_3$ realizes ZVS.

**Mode 6** ($t_5<t<t_6$): The current $i_p$ drops to the zero-crossing at $t_5$ and the switches $Q_3$ and $Q_2$ provide the access for the current $i_p$.

**Mode 7** ($t_6<t<t_7$): The transformer leakage inductor and the parasitic capacitor of the rectifier diodes resonates with the clamping capacitor $C_5$ to charge the $C_5$.

**Mode 8** ($t_7<t<t_8$): The clamping switch $Q_5$ is turned on at $t_7$, the direction of the resonant current $i_{C5}$ remains unchanged. The current $i_{C5}$ decreases to zero at $t_8$.

**Mode 9** ($t_8<t<t_9$): At $t_8$, the current $i_{C5}$ is increasing in reverse direction, and the clamping capacitor $C_5$ is in the discharge state. The energy absorbed by the snubber in mode 7 and 8 is fed back to the load.

## 3. Results

### A. Simulation results

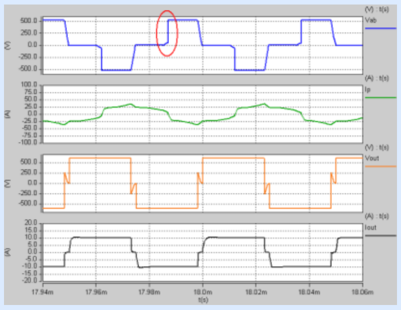

**Figure 3.** The main waveforms of the proposed converter in the passive soft-switching mode.

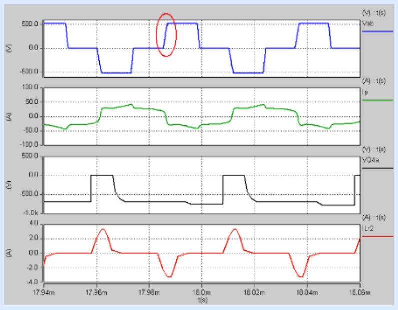

**Figure 4.** The main waveforms of the proposed converter in the active soft-switching mode.

By comparing the voltage of $V_{ab}$ in Fig. 3 and Fig. 4, when the output power is 6.1kW, the lagging switches cannot achieve ZVS in the passive soft-switching mode. When the auxiliary switch is turned on, the lagging switches realize ZVS.

### B. Experimental results

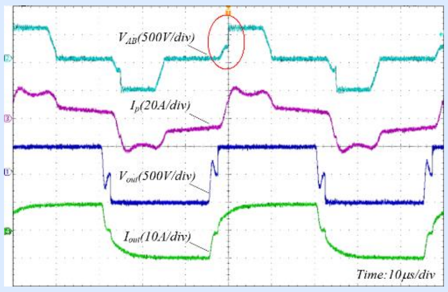


**Figure 5.** The main waveforms of the proposed converter in the passive soft-switching mode.

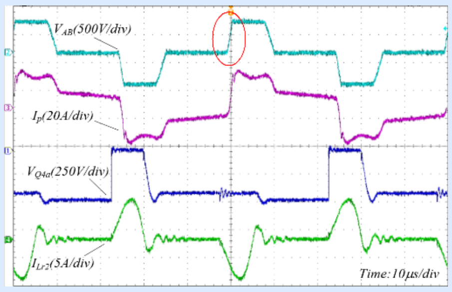


**Figure 6.** The main waveforms of the proposed converter in the active soft-switching mode.

By comparing the waveforms of $V_{AB}$ in Fig. 5 and Fig. 6, when the output power is 5.0kW, the lagging switches achieve ZVS in the active soft-switching mode. The simulation and experimental results are consistent.

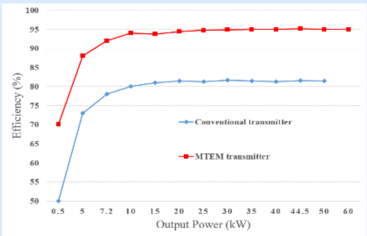


**Figure 7.** Measured efficiency of the MTEM transmitter and the conventional transmitter.

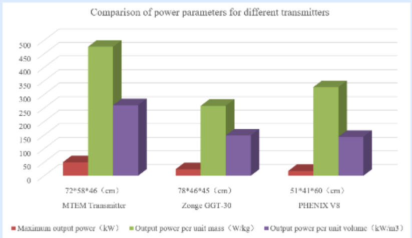


**Figure 8.** Comparison of different transmitters' power parameters

## 4. Conclusions

In this paper, a novel active soft-switching converter with loss-less snubber for the MTEM transmitter is proposed.

Firstly, the topology of the active soft-switching converter with loss-less snubber is introduced and the 18 operating modes of the proposed converter are analyzed in detail. Secondly, the design processes of the converter are presented. Finally, a Saber simulation is carried out and a 60kW prototype is proposed. The theoretical analysis, the simulation results, and the experimental results are consistent and have verified the correctness and validity of the proposed converter.

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