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The Control Circuit for Class E Isolated dc/dc Converter Using Class E Low *dv/dt* PWM Synchronous rectifier

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1. Abstract

The control circuit for class E isolated dc/dc converter regulates the output voltage at fixed switching frequency is presented. The class E isolated dc/dc converter consists of class E series-resonant inverter, high-frequency transformer (T_1) and class E low *dv/dt* PWM synchronous rectifier. The class E inverter is driven by fixed switching frequency (v_{g1}), and the series-resonant circuit (L_r-C_r) tunes the inverter switch voltage (v_{s1}) to high-frequency ac current to drive the high-frequency transformer. By controlling the conduction time of controlled switch in rectifier (S_2), high-frequency ac current will be rectified and the output voltage can be controlled at the same time; the ZVS condition of all switches can be maintained from full-loaded to open-loaded.

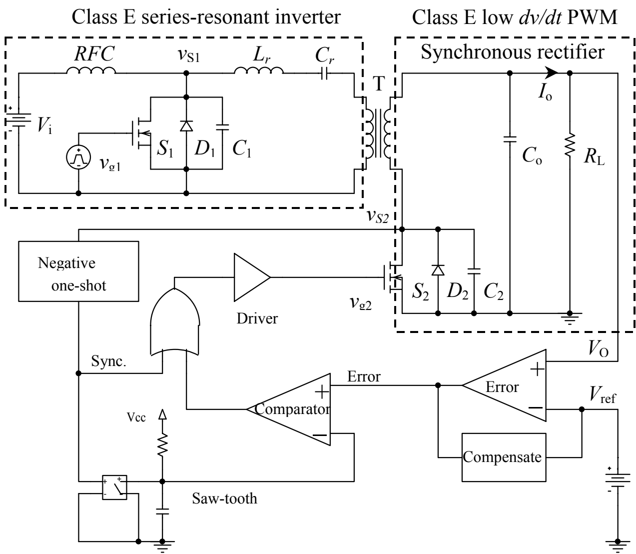
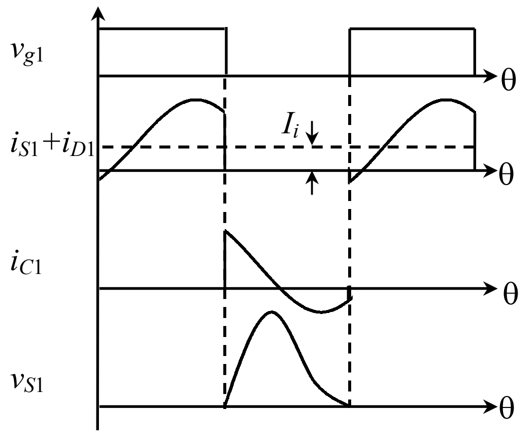


Figure 1. Class E isolated dc/dc converter using class E low *dv/dt* PWM synchronous rectifier with control circuit.

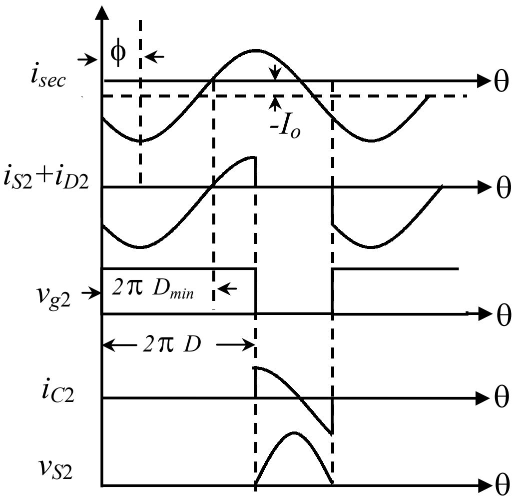
2. Introduction

Class E inverter can be operated at very high switching frequency and high conversion efficiency [1]-[4], and it was applied to many applications. Isolated dc/dc power converter [7]-[12] is an application of class E inverter. Many published papers presented various circuits of class E isolated dc/dc converter and its control method. The frequency modulation control is basic method that applied to inverter switch [5],[6]; the operating frequency is varied to against the variation of load or line voltage.

To avoid the problems of variation of operating frequency [7],[8], the class E converter operates at fixed switching frequency were presented. By using the fixed switching frequency operation, the controlled switch will replace the diode rectifier used in the frequency -modulation type of converters [5],[6], and apply varied duty ratio or PWM signal to drive controlled switch.



(a)



(b)

Figure 2 Typical operating waveforms of converter (a) class E inverter, (b) class E low *dv/dt* PWM synchronous rectifier.

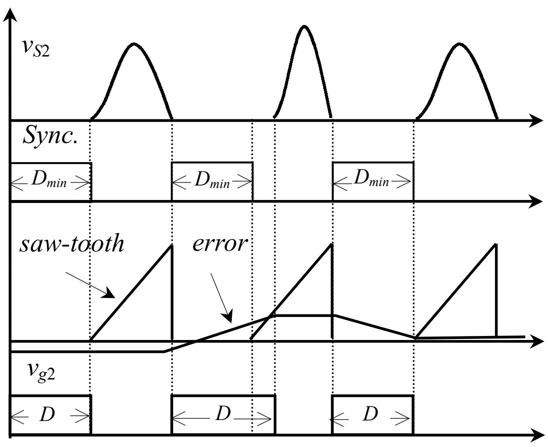


Figure 3. Applied PWM operating waveforms

3. Circuit Operations

The secondary current of transformer consists of induced current from primary and output dc current (I_o). The output dc current (I_o) is calculated by averaging two currents of S_2 and D_2. The controlled switch S_2 is driven by v_{g2} from 0 to $2\pi D$. The conduction time of S_2 begins at the time at the origin of the graph of fig. 2(b), the time when the cathode of D_2 reaches zero volts with respect to the anode, after previously having been positive with respect to the anode. C_2 shapes voltage across S_2 so that the switch turn on and off at low *dv/dt* or zero-voltage. The proposed of drive S_2 are two functions 1.) Rectification of the high-frequency ac current to output dc current, 2.) Regulation of the output voltage at desired value. The conduction time or duty ratio (D) of S_2 will be varied to regulate output voltage against to the variation of load or variation of line voltage. The control interval of D is $D_{\min} \le D < 1$. The regulation of the output voltage can be described as follows.

1. When $D=D_{min}$, S_2 and D_2 conduct the negative current only. The conduction time of S_2 is equal to the conduction time of D_2 and I_o is the maximum.
2. When D=1, S_2 and D_2 conduct all cycle and I_o equal zero.

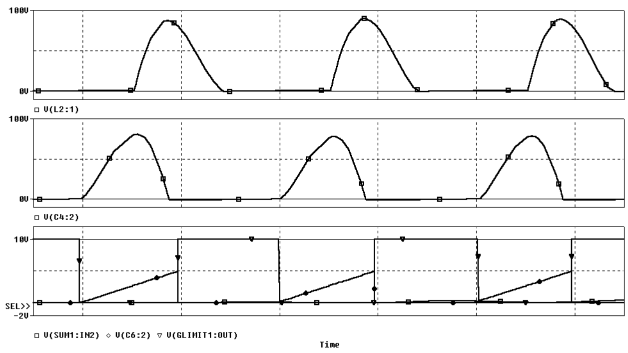
When the duty ratio D is $D_{\min} \le D < 1$, a part of the positive current of i_{S2} flows through S_2. The averaged current through S_2 and D_2 are some value between 0 and the values corresponding to D.

In fig. 3, the synchronous signal (*Sync.*) is generated by the negative-edge one-shot circuit, which synchronized with v_{C2} when decrease to zero volt. Pulse width of *Sync* signal is constant and equal to D_{min} of the rectifier. The pulse width of v_{g2} or duty ratio (D) is equal to $D = D_{\min} + \Delta D$, where ΔD is depended on the output of error amp.

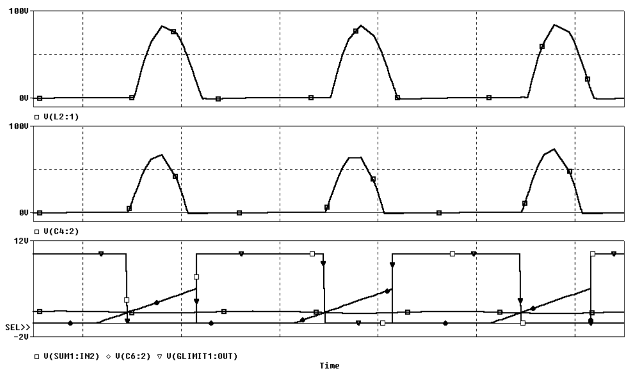
Since the inverter and rectifier is separated by transformer and the inverter act likes a high-frequency sinusoidal current source, multiple rectifiers with individual secondary coil can be paralleled to supply the multiple outputs or supply +/- voltages.

4. Simulation Results

To show the operation, we use [2] to design the inverter with duty ratio=0.5, and use [13]-[14] to design the rectifier at D_{min}=0.5. The example of converter following in specifications V_o=18V at R_{Lmin}=18Ω. Input voltage=20V and operating frequency=1MHz. In simulation, we use model of IRLU120N as switches S_1 and S_2, RFC=100uH, C_1=2.787nF, C_2=2.832n, L_r=8.65uH, C_r=5.17nF and C_o=5uF



(a)



(b)

Figure 4. Simulation waveforms, (a) full load (18Ω), (b) 30% of full load (60Ω)
Top: inverter switch voltage (v_{S1}), Middle: rectifier switch voltage (v_{S2}), Bottom: error voltage, synchronized saw-tooth signal and gate voltage (v_{g2})

Figure 4 show the simulation waveform when the input and output voltage were fixed at 20V and 18V respectively. Figure 4(a) shows the switches voltage and control signals when the converter was loaded by full-load and 4(b) when loaded by 30% of full-load.

5. Conclusion

The advantages of the proposed control circuit with class E isolated dc/dc converter using class E low *dv/dt* PWM synchronous rectifier can be summarized following

1. Operated at very high switching frequency (above 1MHz) with high conversion efficiency; small size and low weight.
2. Regulated or control output at fixed switching frequency; prevent the wide-band noise problem.
3. Turn-on and off with zero voltage switching from full-loaded to open-loaded; low switching loss, low EMI and RFI noise.
4. Can parallel the multiple rectifiers for multiple outputs converter application by using one inverter and one transformer.
5. Low counter parts.

Acknowledgment

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