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A new variable-mode control strategy for LLC resonant converters operating in wide Input voltage range

Key words: LLC, full-bridge, half-bridge, variable-frequency, phase-shift, wide input voltage range

Corresponding author: Zheng-yu Lu
E-mail: eeluzy@cee.zju.edu.cn
ORCID: http://orcid.org/0000-0003-1032-2938

Motivation

- To overcome the shortcomings of traditional LLC resonant converter, this paper adopts Variable-Mode Control strategy to realize higher efficiency in wider range.
- In the so-called Variable-Mode Control strategy, with no change in connection relation of the circuit, the converter proactively controls modes to shift it into specific circuit formation and operating mode.
- With this new Variable-Mode Control strategy, i.e., adopting different circuit modes in accordance with different input voltages, range of input voltage could be widened, MOSFET operating frequency reduced, circuit design facilitated, excitation loss and circuit loss decreased, and efficiency maximized.

Main idea

- A new Variable-Mode Control strategy that is applicable for LLC resonant converters operating in wide input voltage range.
- This control strategy incorporates advantages of full-bridge LLC resonant converters, half-bridge LLC resonant converters, the variable–frequency control mode, and phase-shift control mode.

Method

When input voltage is fairly low, a FB-VF Mode would be adopted; when it gets higher to a certain extent, a full-bridge phase-shifting mode (FB-PS Mode) would be adopted; when it keeps rising, a half-bridge variable frequency mode (HB-VF Mode) would be employed.

Major results

- The new control strategy that enables LLC resonant converter to work with ultra-wide voltage range.

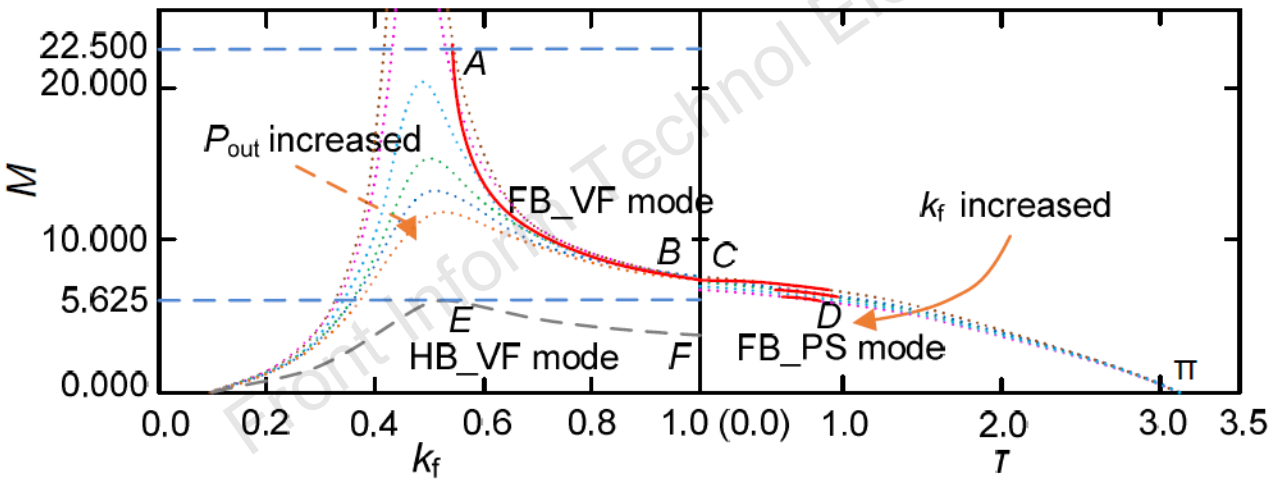
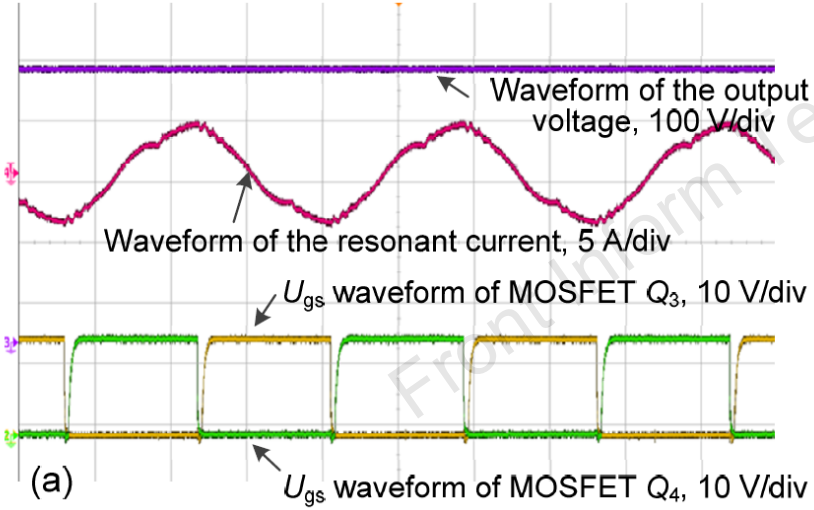


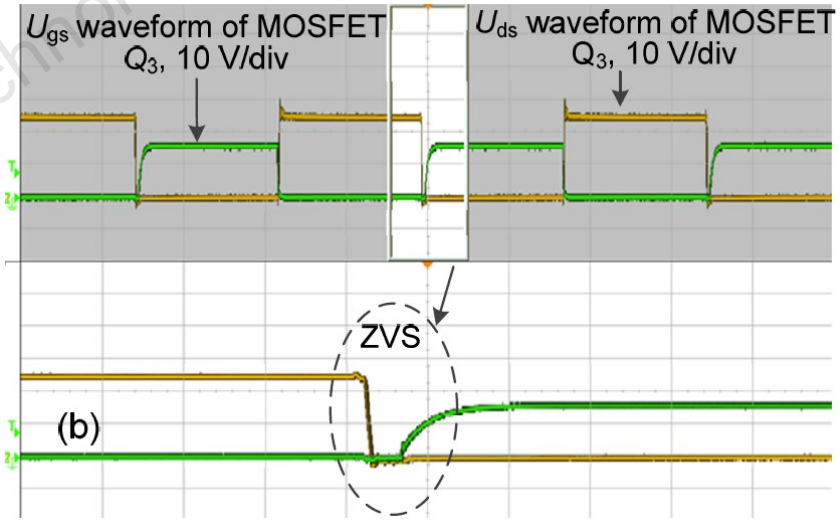
Fig. 17 Voltage gain variation curves for switching among three modes

Major results (Cont'd)

- Mode 1 FB_VF: the circuit works in FB-VF Mode and with light load on primary winding MOSFET, ZVS could easily be realized.



(a) Waveforms of resonant current and output voltage



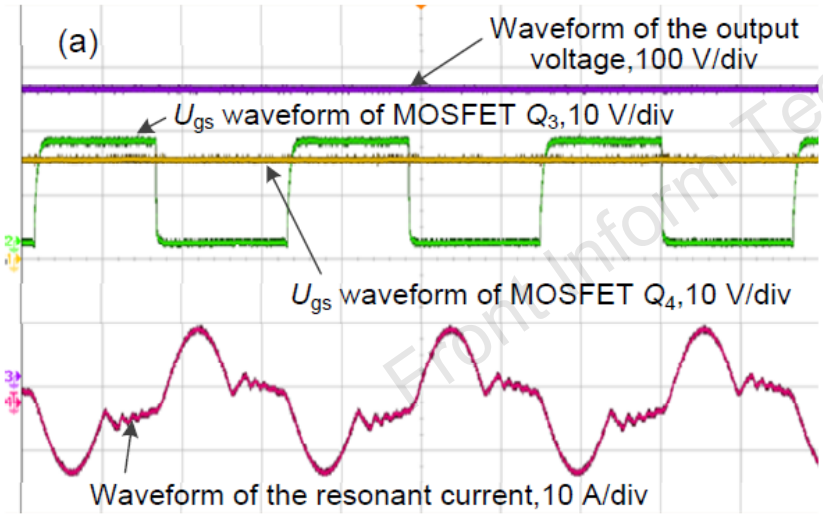
(b)Waveforms of U_{gs} and U_{ds} of primary winding MOSFET

Fig.18 FB-VF Mode of LLC resonant converter

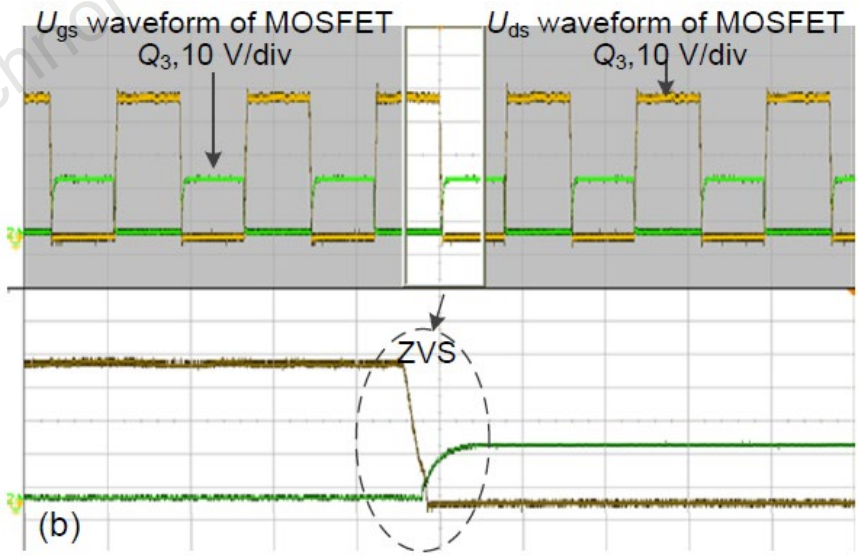
(Testing conditions: U_{in}=25V, U_o=450V, P_{out}=25W)

Major results (Cont'd)

- Mode 2 FB_PS: the circuit works in FB-PS Mode and with full load on primary MOSFET, ZVS could also easily be realized.



(a) Waveforms of resonant current and output voltage



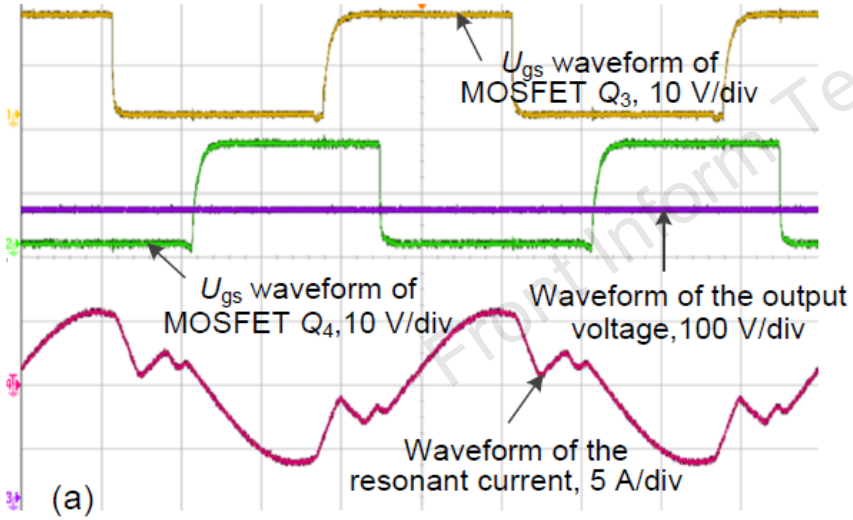
(b) Waveforms of U_{gs} and U_{ds} of primary winding MOSFET

Fig.19 FB-PS Mode of LLC resonant converter

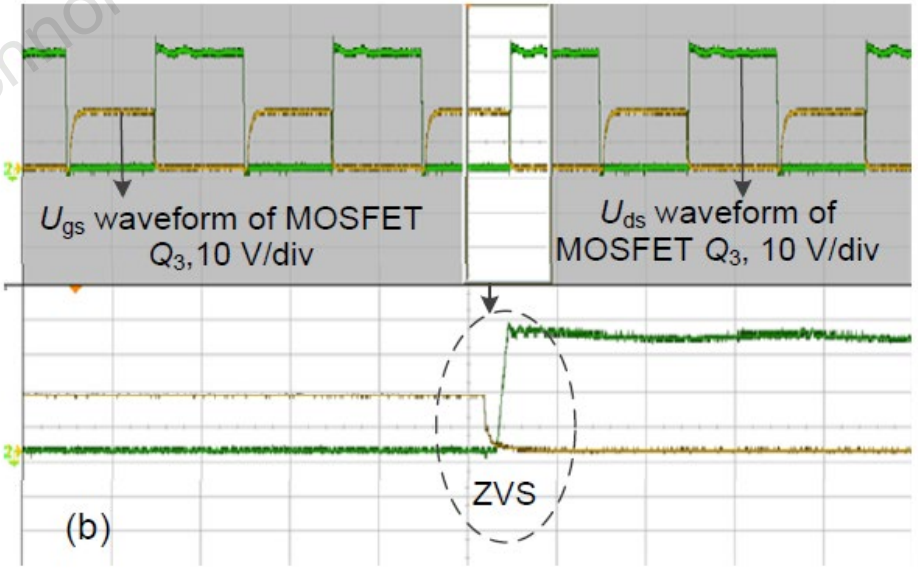
(Testing conditions: U_{in}=65V, U_o=450V, P_{out}=300W)

Major results (Cont'd)

- Mode 3 HB_VF:the circuit works in HB-VF Mode and with full load on primary winding MOSFET, zero-voltage start could also easily be realized.



(a) Waveforms of resonant current and output voltage



(b) Waveforms of U_{gs} and U_{ds} of primary winding MOSFET

Fig.20 HB-VF Mode of LLC resonant converter

(Testing conditions: U_{in}=90V, U_o=450V, P_{out}=300W)

Conclusions

- Through shifting between half bridge and full bridge, input voltage range could be doubled. Furthermore, with the full-bridge phase-shifting mode, input voltage range could further increase.
- After experimental verification, it has been proved that the converter under Variable-Mode Control strategy has a higher efficiency than that under traditional strategies.
- The proposed control strategy verified. Experimental results show that under this control strategy, the maximum converter efficiency reaches 95.7% and the range of input voltage expands by 3 times.