Design and Development of Pulse Ignition for HID Lamp Electronic Ballast with ZVS-QSW Converter

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Abstract— In this paper, a novel pulse ignition circuit is proposed for electronic ballast with the zero-voltage-switching quasi-square wave (ZVS-QSW) converter; the voltage pulse of the proposed igniting circuit contains both a high frequency part and a low frequency part; the high frequency part made it easy to exit the gas in the ionization conduction state in the high-intensity discharge lamp, and the low frequency part makes it easy to lower the igniting potential and provides the continuous pulse energy. A special microcontroller for a HID ballast is used to raise the control performance, and the low-frequency square-wave control method is adopted to avoid acoustic resonance. A 70W prototype was built in the laboratory. Experimental results show that the electronic ballast works reliably. Furthermore, the efficiency of the ballast can be higher than 92%.

Key words: Electronic ballast, metal halide lamp, pulse igniting, zero-voltage-switching, zero-voltage-switching quasi-square wave (ZVS-QSW)

I. Introduction

High intensity discharge (HID) lamps have excellent characteristics with high lighting efficiency, good color rendering (e.g., metal halide (MH) lamp), and longer lifetime. Therefore, HID lamps are widely used to satisfy high quality lighting fields and commercial lighting systems. The low power metal halide lamp is widely used nowadays. The traditional driver is the magnetic ballast, which has large weight, high volume, low power factor (PF), high total harmonics distortion (THD), and the output power ranges with the input voltage. Since the electronic ballast has low weight, low volume, high-PF, low-THD, and the power closed loop can be realized, it will take the place of the magnetic ballast in the future [5].

The traditional topology for the LFSW electronic ballast is a bridge-type converter, since the full bridge converter has four switches, which increases the costs of the system, the half bridge converter is very widely used, but since the switches work in the hard switching state, which increases the switching losses and lowers the efficiency of the system[2].To improve the power density, a zero-voltage-switching quasi-square wave (ZVS-QSW) converter is adopted in paper, since the switches work in the soft switching state, both the efficiency and the power density of the system increase.

There are usually two methods to ignite the metal halide lamp, the first method is the resonant igniting method, since no additional components are needed, the igniting method is very easy to be realized. But when the lamp is in the open-circuit state, the voltage and the current in the main circuit are both very high, so the protection function must be made. The second method is the pulse igniting method. The pulse igniting method requires adding additional components to the system, so the costs increase, but there is no high current in the main circuit when the lamp is in the open-circuit state.

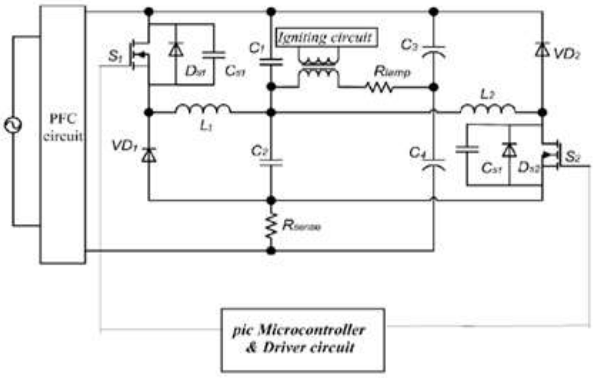

Fig. 1: Novel two stage dual Buck topology

II. Configuration of the Ballast

It can be seen from Fig. 1 that the single entry AC passes through the filter circuit to curtail the electromagnetic interference. Then the voltage signal passes through the rectifying bridge and it changes into a single entry DC. Then the signal passes through the power-factor correction (PFC) circuit, so that a 400V dc bus voltage is produced. The last part of the circuit is the main circuit which is a dual-buck inverter circuit and its functional mode is controlled by a chip microprocessor. Here a MC33262 Chip is chosen to realize the power factor correction.

A. ZVS-QSW Converter

Fig. 1 shows the dual buck converter adopted in this paper. The bus voltage is 400V provided by a PFC circuit. The power field effect tube S1 and the ultra-fast-recovery diode V D1 form one bridge arm, and S2 and V D2 form the other bridge arm. Ds1 and Cs1 are the body diode and the output capacitance of S1. Ds2 and Cs2 are the body diode and the output capacitance of S2.L1 and L2 are the filtering inductance of the buck circuits. C1 and C2 are the filtering capacitance of the buck circuits. C3 and C4 are not only the half bridge capacitance, but also the output capacitance of the PFC circuit. Rlamp is the equivalent resistance of the lamp in the steady state. In the circuit, S1, V D1, L1, C1 and C2 form one buck circuit while S2, V D2, L2, C1 and C2 form the other buck circuit

The circuit has two working modes, and the drive signals of the switches are shown in Fig.2.2.1 and Fig.2.2.2. When the switch S1 works with a high working frequency and S2 is turned off, the circuit works in mode1. When the switch S2 works with a high working frequency and S1 is turned off, the circuit works in mode2. Therefore, the converter works in two modes in a low frequency and the load gets a low-frequency square waveform.

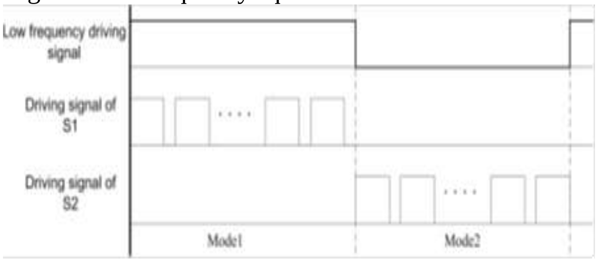

Fig. 2.1.1: Working modes of the switches.

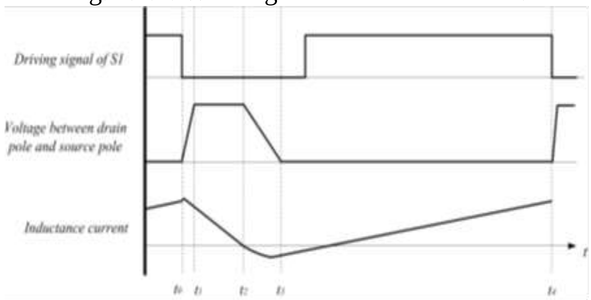

Fig. 2.2.2: Drive signal of the switch.

III. PULSE IGNITION

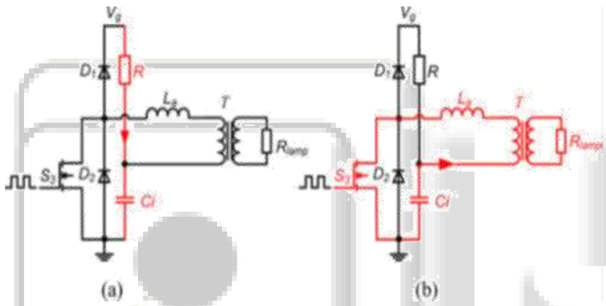

Fig. 3.1: Working modes of the igniting circuit.
(a) Charging process. (b) Discharging process.

The pulse igniting circuit is made up of S_3,D_1,D_2,R, L_a, C_i and the transformer in Fig. 3.1. Here R is the current limiting resistance, D_1 and D_2 are the clamping diodes, which makes sure that the voltage between the drain pole and the source pole of $S3$ is limited from V_g to 0 V. There is a high voltage pulse in a half-low frequency period to ignite the lamp. There are two working modes for the igniting circuit. First, S_3 is in turned off, C_i is charged until the voltage of Ci reaches V_g . Second, after the voltage of C_i reaches V_g, S_3 is turned on, C_i discharges through L_a and the transformer, one resonance tank is made up of the primary inductor L_p, the auxiliary inductor L_a and the energy storage capacitor C_i , the other resonant tank is made up of La , and the parasitic capacitance of the transformer, so the dual frequency trigger voltage pulse to ignite the lamp is obtained from the secondary side of the transformer. When the lamp is ignited successfully, S_3 is always in the turned-off state, the voltage of C_i is always equal to the bus voltage, but there is no discharging loop for C_i, so the igniting circuit does not affect the operation of the ZVS-QSW converter in [8], and the working modes are shown in Fig. 3.1.

The traditional switching component for S_3 is the spark gap or SCR. But the life time of the spark gap is very short, which limits the spark gap used for the igniting circuit. The working frequency of SCR is not very high, so it's not suitable to use it here. The reliability of IGBT component is high with simple drive circuit, so here IGBT is chosen to be the switch for S_3 .

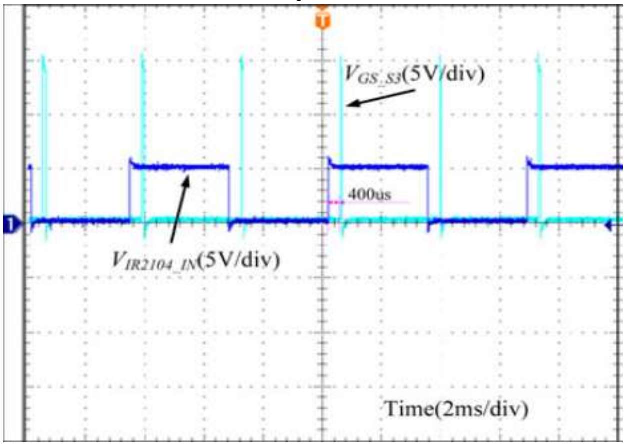

Fig. 3.2: Driving voltage of $S3$ and the voltage of IR2104 S_IN pin

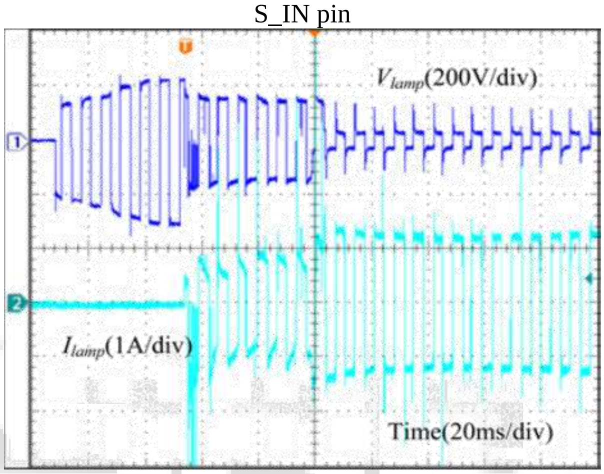

Fig. 3.3: Lamp current and lamp voltage in the igniting stage.

IV. EXPERIMENTAL RESULTS

This paper uses the 70-W metal halide lamp, and its type is PHILIPS MHN-TD 70 W. $S3$ is chosen to be STGD7NB60K, and the driving IC is IR2104 S. Driving voltage of S_3 is shown in Fig.3.2. Here the energy storage capacitor is chosen to be 15 nF/630 V, and it is film capacitor with low ESR. The auxiliary inductor is 30μH, the word inductance with the size 10 mm×12 mm is adopted, and the wingding is enameled wire with 0.5-mm diameter.

For the design of the turn ratio of the transformer, first, the amplitude of the voltage pulse must be higher than 3 kV. Second, the loop current must be lower than 10 A. Third, the high voltage pulse lasting time must be larger than 1μs. so the turn ratio is chosen to be 8. The core of the transformer is EE18 mm×20 mm, the sandwich winding method is adopted here, the enameled wire with 0.4 mm diameter is used, and L_p is 17.8μH. Also, in practical use, the manufacturing tolerances or the temperature does not affect the igniter capacitances/inductors and the igniting voltage significantly. since the value of C_i is selected to be 15nF, even with 5% of the deviation, the amplitude of the pulse voltage is still higher than 3 kV, and the loop current is still lower than 10 A. Since the ZVS-QSW converter is adopted here, the switching losses are very low, the efficiency is very high, and the temperature rise of system is very low. So the temperature effect does not affect the igniter capacitances/inductors, and hence affect significantly the ignition voltage.

V. CONCLUSION

In this paper, a metal halide pulse igniting circuit based on the dual frequency trigger pulse method is proposed, and it's very suitable to be used for the metal halide lamp electronic ballast with the ZVS-QSW converter. It adds an auxiliary inductor in the traditional pulse igniting circuit and uses the parasitic capacitance of the transformer to generate two groups of ignition pulse sequences with different frequencies applied to the lamp. It is observed that it can avoid acoustic resonance, and that the switches of the converter work in the ZVS state.

It can also be seen that the efficiency is as high as 92%. Meanwhile, the one-cycle-peak-current control proposed here makes sure that the excessive current during the commutation period and the transition stage can be limited to a safe value for the converter. This improves the reliability of the system a lot.

REFERENCES

[1] Yijie Wang, Student Member, IEEE, Huaiyuan Liu, Xiangjun Zhang, Dianguo Xu, Senior Member, IEEE,"A Pulse Igniting Circuit for Electronic Ballast With the ZVS-QSW Converter" IEEE Transactions On Power Electronics, Vol. 29, No. 6, June 2014
[2] Tsorng-Juu Liang, Member, IEEE, Chien-Ming Huang, and Jiann-Fuh Chen, Member, IEEE "Two-Stage High-Power-Factor Electronic Ballast for Metal–Halide Lamps" IEEE Transactions On Power Electronics, Vol. 24, No. 12, December 2009
[3] Nan Chen, Student Member, IEEE, and Henry Shu-Hung Chung, Senior Member, IEEE "Energy-Recyclable Burn-In Technology for Electronic Ballasts" IEEE Transactions On Power Electronics, Vol. 26, No. 9, September 2011
[4] Ryan W. Schnell, Regan A. Zane, Member, IEEE, and Francisco J. Azcondo, Senior Member, IEEE "Size Reduction in LFSW Ballasts for High-Intensity Discharge Lamps Using Soft-Saturation Magnetic Material and Digital Control Techniques" IEEE Transactions On Power Electronics, Vol. 28, No. 2, February 2013
[5] Hung-Liang Cheng, Member, IEEE, Chin-Sien Moo, Member, IEEE, Chung-Sheng Yang, and Chun-Kai Huang "Analysis and Implementation of an HPF Electronic Ballast for HID Lamps With LFSW Voltage" IEEE Transactions On Power Electronics, Vol. 27, No. 11, November 2012.
[6] André Luís Kirsten,Marco A. Dalla Costa, Cassiano Rech, Ricardo Nederson do Prado,and Tiago Bandeira Marchesan, Member, IEEE "Digital Control Strategy for HID Lamp Electronic Ballasts " IEEE Transactions On Industrial Electronics, Vol. 60, No. 2, February 2013.
[7] Hung-Liang Cheng, Member, IEEE, and Ping-Wen Wang "A Novel Single-Stage High-Power-Factor Electronic Ballast for Metal-Halide Lamps Free of Acoustic Resonance" IEEE Transactions On Power Electronics, Vol. 26, No. 5, May 2011
[8] Y. Wang, D. Xu, W. Wang, X. Zhang, and B. Xu, "Electronic ballast for metal halide lamps using a quasi-resonant inverter with digital control," IEEE Trans. Ind. Electron., vol. 59, no. 4, pp. 1825–1840, Apr. 2012.

