Development of High-Speed and High-Voltage Pulse Generator Using Multi-Toroidal-Core Transformer

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I. INTRODUCTION

This paper focuses on a low-temperature plasma NO_x decomposition method, and an application of power electronics is attempted to generate ultra-high-speed and high-voltage pulse for the plasma reactor. There have been many methods reported to decompose NO_x such as a low-temperature plasma decomposition method using corona discharge [1]. The paper discusses practical implementation techniques to reduce the line inductance, to achieve simultaneous high-speed switching of multiple parallel-connected MOSFETs, and to make the compact mechanical configuration possible.

II. PROTOTYPE DESIGN

Fig. 1 shows a main circuit schematic diagram of the high-speed and high-voltage pulse generator. The voltage is stepped up through the first stage from 12 VDC to 420 VDC. On the second stage, MOSFETs Q_1-Q_{12} are employed to achieve simultaneous switching, and are connected to the primary windings of the toroidal multi-core transformer. The total voltage step-up ratio of the second stage is 24 times. The following equations are used for the design of the toroidal multi-core transformer:

$$V_1 = \frac{2}{D} B_m S N_1 f \text{ , and} \tag{1}$$

$$V_2 = n\frac{2}{D} B_m S N_2 f \text{ ,} \tag{2}$$

where V_1 is a primary voltage, V_2 is a secondary voltage, N_1 is a primary number of turns, N_2 is a secondary number of turns, B_m is magnetic flux density, S is a section area of each toroidal core, f is an operating frequency, n is a toroidal core count. The peak voltage of the output pulse can be determined by the turn ratio of the transformer and the number of the toroidal cores.

III. COMPUTER SIMULATION TEST RESULTS

It is required to satisfy the voltage rise time less than 100 ns to the peak over 10 kV to increase the NO_x decomposition rate. Fig. 2 shows a computer simulation test result to check the influence of the line inductance. It can be found from Fig. 2 that the output voltage can achieve more than 10 kV within 50 ns which implies that the proposed design has low internal inductance. An output voltage pulse train waveform is shown in Fig. 3. It is confirmed from this result that 1-ms cyclic voltage pulse with as fast rise time as 50 ns and as high voltage as 10 kV is obtained.

IV. CONCLUSION

This paper discussed a compact high-speed and high-voltage pulse generator for a NO_x decomposition plasma reactor. It has been confirmed through several computer simulation tests that the pulse generator prototype achieved as fast-rise-time as 50 ns and as high-voltage as 12 kV.

REFERENCES

[1] N. Tsuji and S. Kondo, "Development of High Efficiency Low-Voltage / High-Current DC Power Supply," *IEEJ Semiconductor Power Conversion Technical Meeting,* SPC-03-141, 2003, pp. 45-50.

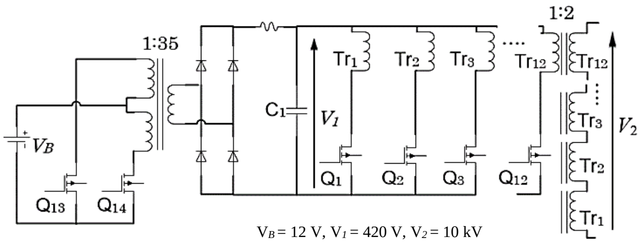

Fig. 1. Configuration of main circuit.

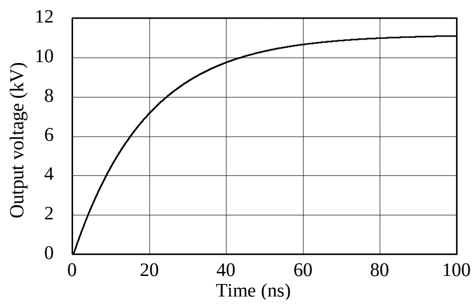

Fig. 2. Simulation result of output pulse transient behavior.

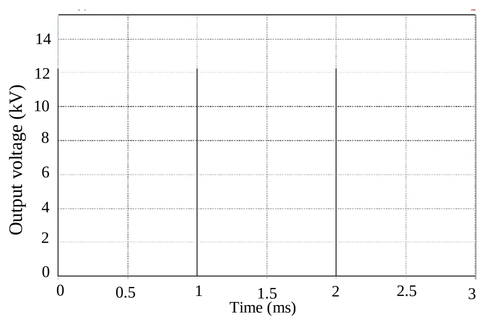

Fig. 3. Simulation result of voltage pulse train waveform.