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Repetitive High Voltage Pulse Modulator Using Bipolar Marx Generator Combined with Pulse Transformer

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All-solid-state Marx generator is mature approach to obtain repetitive high voltage pulses and many topologies have been proposed. However, due to limited rated voltage of semiconductor switches, a large amount of switches is required. Too much switches, in addition with high repetition rate, lead to severe stray parameters and heat dissipation. It increases the difficulty of structure design and reduces system reliability. Moreover, the inconsistency of massive switches slows down rise and falling edges of pulses. Therefore, how to enhance reliability of repetitive high voltage modulators has always been the research hotspot and difficulty. Marx topology combined with step up pulse transformer is proposed in [1]. But only unipolar Marx combined with pulse transformer is discussed.

In this paper, a pulse modulator which consists of a bipolar Marx generator combined with a pulse transformer is proposed. The bipolar Marx generator is composed of a series connection of full bridge switch-capacitor cells (SCCs) [2]. A ten-SCCs stage Marx generator can output ± 8 kV voltage pulses. A step up pulse transformer with a ratio of 1:5 is connected to the output of Marx generator. Thus, the amplitude of output voltage pulse at load can be 40 kV. The use of pulse transformer also enables zero current switching of IGBTs. Therefore, switching losses are reduced. Higher turn ratios, such as 1:40, will further reduce the amplitude of primary voltage. However, it will lead to larger leakage inductance and parasitic capacitance, and degrade the shape of voltage pulses.

A laboratory prototype of the proposed pulse modulator is implemented. It operates with a voltage amplitude in the range of 0-40 kV. The repetition rate can be adjusted from 0.1 Hz to 10 kHz and pulse width can be adjusted from 2 μ s to 5 μ s. The rise time of voltage pulses are less than 400 ns. Over voltage, short circuit, and temperature protects are taken into account. Experiments with homemade DBD shows that the pulse modulator can work in rated parameters reliably. Electrical model of pulse transformer and DBD reactor are developed and simulation analysis is carried out. The simulation results agree well with experiment results.

[1] L. M. Redondo and J. F. Silva, "Repetitive High-Voltage Solid-State Marx Modulator Design for Various Load Conditions," IEEE Trans. Plasma Sci., Vol. 37, No. 8, pp. 1632-1637, Aug. 2009.

[2] T. Sakamoto, and H. Akiyama, "Solid-State Dual Marx Generator with a Short Pulsewidth", IEEE trans. Plasma Sci., Vol. 41, No. 10, pp. 2649-2653, Oct. 2013.

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