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The Design and the First Test Results of a Fast LTD Stage

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Linear transformer driver stages are designed to be used as a primary energy storage in high power pulsed generators. In this report, the design and test results of the linear transformer driver stage prototype that delivers ≈ 100 kA fast pulse with 133 ns FWHM into a ≈ 0.87 Ω resistive load are described. This stage consists of 20 (100 kV, 20 nF) storage capacitors that are arranged in 10 identical bricks located evenly around the axis of the stage. Each brick contains two capacitors, a multi-gap switch, and the output connector that transfers the energy to the resistive load. The outer diameter of the stage is ≈ 1.5 m, at a length of ≈ 20 cm. The stage is developed to demonstrate the possibility of the fast linear transformer driver technology to create high power pulsed generators.

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1. Introduction

Linear transformer driver (LTD) technology was developed at the High Current Electronics Institute (HCEI) in Tomsk, Russia [1]. There exist some applications like Z-pinch, hydrodynamic radiography, high power microwave, which require power pulse in the load with the width of ≈ 100 ns or less [2]. Traditional pulsed power generators get such pulses by using several pulse forming stages [3]. However, the fast LTD generators can produce high power pulses directly. This makes it more compact and inexpensive.

The fast LTD stage consists of some bricks connected in parallel and triggered simultaneously [4]. In each brick, two storage capacitors are charged in opposite polarity. When the switch is triggered, the output pulse is applied on the load through inductive isolation. Higher current can be achieved with many capacitors connected in parallel in a circular array. Higher voltage can be obtained by inductively adding many stages in series.

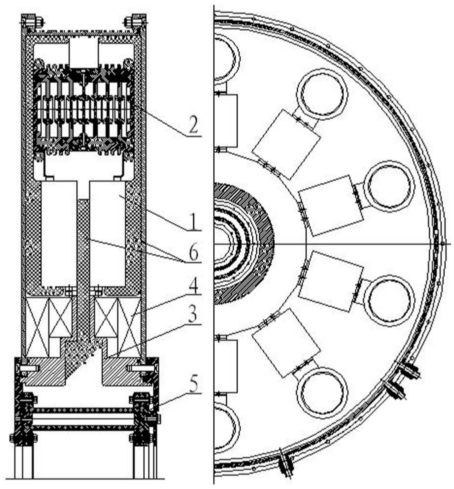

Fig. 1. Design of the LTD stage.

2. Design of the LTD stage

The design of the fast LTD stage is given in Fig. 1. It consists of 10 identical bricks located evenly around the axis of the stage. Each brick contains two serial capacitors, 1, a multi-gap switch, 2, and the output connector, 3, that transfers the energy to the resistive load. The high voltage terminals of the capacitor locate on opposite sides of the body making it more compact and convenient for assembly into the LTD stage. The magnetic core, 4, consists of four rings. Each ring is wounded of 25 μm thick, 20 mm wide Metglas tape. The turns in the rings are insulated with polyester film and fixed with epoxy. Total effective cross-section of the core is ≈ 100 cm^2.

The capacitors in the brick are charged in opposite polarity to ±85 kV, so the open circuit output voltage of the stage is 170 kV. The stage was tested with a resistive load, 5, which is made as a circular cavity filled with KCl water solution. The insulation is provided by polyethylene insulator, 6, and by filling the cavity with SF_6. The premagnetizing generator resets the magnetic core by delivering ≈ 2.5 kA at 20 kV charge voltage with a pulse width of ≈ 25 μs. The cavity diameter is ≈ 150 cm, and the height is 20 cm. Figure 2 shows the picture of the LTD stage without the top flange and one of the polyethylene insulator.

The load current is measured by a B-dot probe, and the load voltage is measured by a resistive divider that is connected in parallel to the load. The current monitor is calibrated on shots where output terminals are short-circuited.

As we know, the closing switches in LTD stage need to be low inductance, long lifetime and triggered simultaneously. In order to meet these requirements, a multi-gap switch (MGS) is developed in our laboratory. In

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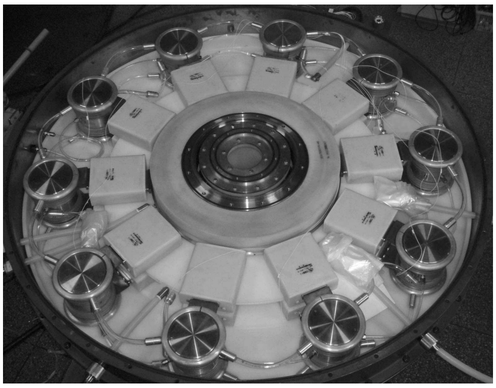

Fig. 2. LTD stage without top flange.

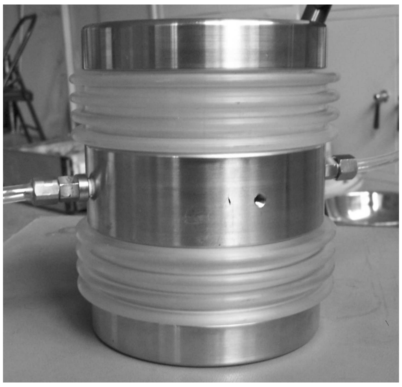

Fig. 3. Photograph of the multi-gap switch.

the switch, the charge voltage is distributed between the electrodes with corona discharges.

The photograph of the MGS is given in Fig. 3. The switch consists of eight gaps of a total length of ≈ 16.2 cm. The switch body is made of polymethyl methacrylate (PMMA). The corona needles are placed on the axis of the switch and screwed on to the disk inside the electrodes. The trigger electrode in the middle is

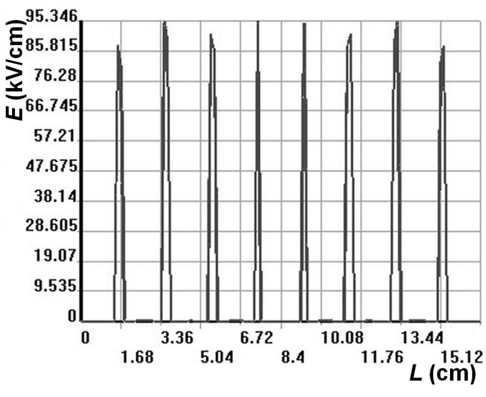

Fig. 4. Axial electric field distribution in the gaps between the electrodes at charging.

at ground potential. The insulating gas inside the switch is mixture of SF_6 and nitrogen at a pressure of ≈ 1 atm. The switches had been tested at ±100 kV in oil before being assembled in the LTD stage.

Figure 4 shows the distribution of the axial electric field in the gaps between the electrodes of the MGS with ±100 kV charge prior to triggering, when the middle electrode is grounded. It is assumed that the corona discharge distributes the charge voltage evenly between the 8 gaps. The peak electric field on the electrode surface is ≈ 95 kV/cm.

3. Test results

The LTD stage was tested with ≈ 0.87 Ω resistive load made of KCl water solution. In order to estimate the power losses associated with the saturation effect of the magnetic core, the experiments have been performed in condition of before or after reset of core. Typical recorded traces at ±85 kV charge voltage are presented in Fig. 5 and Fig. 6.

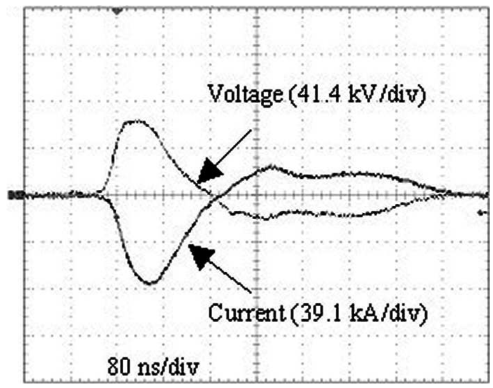

Fig. 5. Recorded traces at ±85 kV charge before premagnetizing the core.

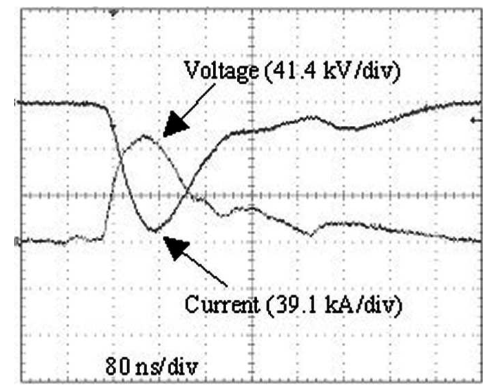

Fig. 6. Recorded traces at ±85 kV charge after premagnetizing the core.

When charged to ±85 kV before reset of core, the stage can provide a current of 76.1 kA in 49.6 ns (10–90% peak value) with the full width at half maximum (FWHM) of 126.4 ns to the 0.87 Ω resistive load. However, the stage can provide a current of 106.5 kA in 52.8 ns with FWHM of 133.2 ns to the same load after reset of core.

Compared with Fig. 6, the current decreased at about 28.5% in Fig. 5 indicating saturation of the core. This saturation is supported also by increased reversal voltage across the load.

4. Conclusions

The fast LTD stage is developed and tested providing ≈ 106.5 kA current pulse into the 0.87 Ω resistive load. The rise time of the pulse is ≈ 52.8 ns.

The stage consists of 20 storage capacitors and 10 multi-gap switches. The outer diameter of the stage is ≈ 1.5 m, and the axial length is ≈ 20 cm.

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