A 500KV PULSER WITH FAST RISETIME FOR EMP SIMULATION

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Abstract

A fast risetime pulser with 500kV rated output voltage for producing the electromagnetic pulse (EMP) is fabricated. It mainly consists of a low inductance Marx generator, a compact independent sealed peaking capacitor, an output switch, and a small amount of gas-sealed insulated containers. Compared with other similar pulsers mentioned in IEC 61000-4-32[1], the insulated containers of the pulser are independent of each other in gas-sealed structure, and its number is less than that of other pulsers. It can be used to drive a guided wave antenna directly to produce an electromagnetic environment, which conformed with the new standard for fast electromagnetic pulse(FEMP) developed by IEC. Output voltage produced by the pulser in dummy load state can reach to 600kV. And, risetime of the waveform is 1.2ns, pulse width (FWHM) being 32ns. When the pulser drives a 10m guided-wave antenna, an output voltage with a risetime of no more than 2.7ns and a FWHM of 30ns are achieved.

INTRODUCTION

Pulsers for FEMP simulation need to produce an essentially double exponential output pulse with a fast risetime of less than 2ns and a falltime of less than 100ns[2][3][4]. Some guided wave simulators with fast pulsers as an important type of EMP simulation system have been constructed, such as DIESES(Germany), NET(France), RIFY(Switzerland), ERU-2M(Russia), etc[1]. Pulsers of these simulators have the similar capabilities of generating about 500kV double exponential output pulse with a fast risetime of less than 2.5ns. But the design principle and the structure of these pulsers are various.

This paper presents a fast risetime pulser with a new structure. Its configuration is simple and easy to assemble. A low-inductance Marx generator with an independent peaking capacitor is used to develop an output voltage of up to 500kV. The rise time of the voltage waveform can reach to 1.2ns, and the pulse duration is about 32ns.

GENERATION OF HIGH-VOLTAGE FAST RISETIME PULSE

High voltage pulse with fast rise time is typically generated by fast discharges. Marx generator is most commonly used for this purpose. However, the inductance of Marx generators at such high voltages generally precludes achieving the required risetime directly. A peaking circuit is usually the solution to achieving the required fast time.

There are three typical pulse-peaking methods. The representative pulsers are EMP-1000 at Munster of Germany, CNET at Lannion of France, and HPD pulse generator at Munster of Germany. The peaking circuit of the improved EMP-1000 consists of a transfer capacitor, a transfer switch, a peaking capacitor, and an output switch[6]. The pulse forming network of the HPD Simulator at Munster consists of a HV feed through and a peaking capacitor[7]. CNET compress the output pulse of Marx generator directly to a fast pulse with a risetime of 2.5ns-4.2ns by a special construction named dielectric lens[1].

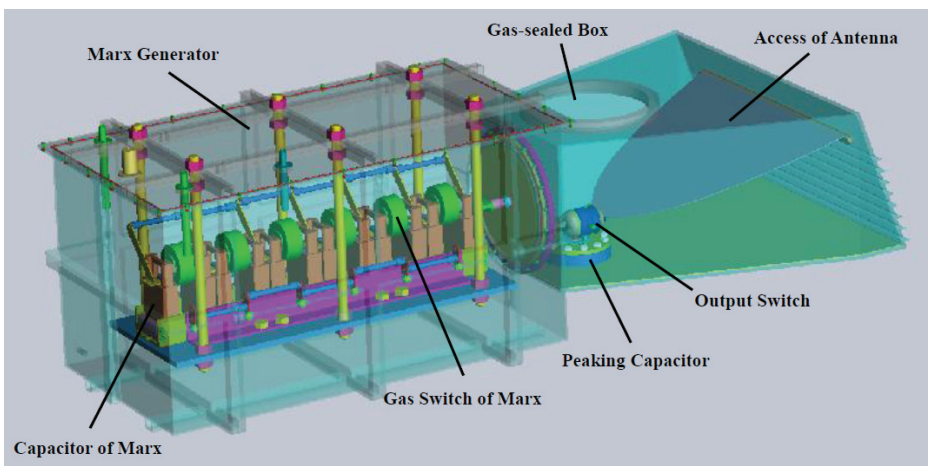


Figure 1: Perspective drawing of the new pulser.

CONSTRUCTION OF THE NEW PULSER

A perspective drawing of the new pulser is shown in Fig. 1. The pulser is composed of a Marx generator, an independent peaking capacitor, an output switch, and a transition structure of antenna.

The Marx generator consists of eight stages, one of which includes two capacitors and a gas switch. They are mounted on a straight plastic support and are entirely immerged in an oil box. Each of the capacitor is 3.6nF in capacitance and 60kV in rated voltage. The gas switch is a spark gap with low inductance. All of the connecting line and the terminal connection of the generator are shortened to reduce the whole inductance. The size of the generator is 1650mm ×800mm×800mm. The total inductance is 1.6uH.

Peaking capacitor is the hard core of this pulser. It's an independent HV capacitor with characteristics of low-inductance, high endurable capability of HV, and compact structure. The capacitance of the peaking capacitor is designed to be 55pF. It has a pancake structure with a diameter of 315mm and a height of 59mm. Its self-inductance is no more than 17nH. And, it is easy for the shape of the peaking capacitor to match the structure of guided wave antenna. The connector between Marx and peaking capacitor is a flexible metal rod, which has the functions of realizing electrical connection and adjusting the circuit inductance.

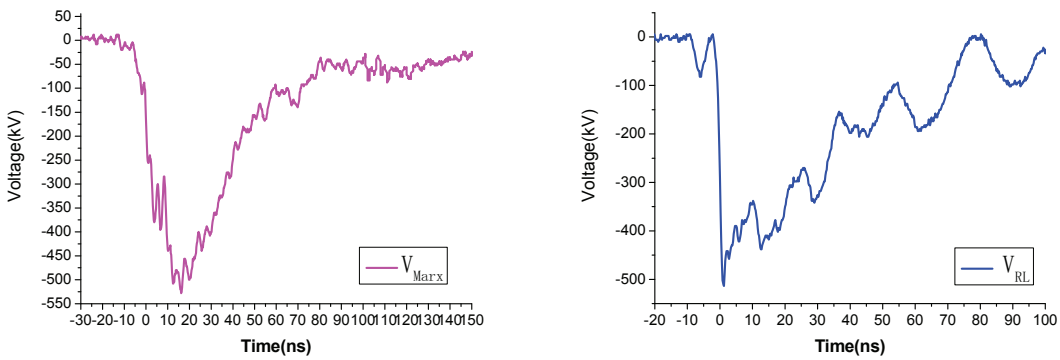
Output switch is a self-breakdown spark gap with two electrodes. Gap space is 6mm. Nonuniformity coefficient of field of the switch is 1.2. Its insulation casing is an organic glass chamber with a diameter of 102mm, and a length of 121mm.

A gas-sealed box that is made of fiberglass reinforced plastics is used to prevent flashover on the diaphragm and surfaces of the peaking circuit. The structure of the gas-sealed box of this pulser is shown in Fig. 1. The profile of the box is a trapezoid with a bottom of 1280mm in length, 600mm in width and a top of 1100mm in length, 600mm in width, and a height of 550mm. The pressure endurable ability of the box is designed to be 0.2Mpa. The connector of Marx and peaking capacitor, the peaking capacitor, the output switch, and the transition structure of guided wave antenna are all contained in this box. Compared with the EMP-1000, the insulated containers of the pulser are independent respectively, gas pressure of which can be adjusted independently.

TEST OF THE PULSER AND ANALYSES OF THE RESULTS

Test of the pulser with matching load

The impedance of antenna drived by the new pulser is 180 Ω. In laboratory study, the transition region of antenna is extended in the length of 2m from the terminal of the gas-sealed box using some conductor wires, which connect to the ground through the matching load. The load is consisted of 12 water resistors which uniformly connected to the extended terminal of the transition section in parallel. Each resistor has a resistance of 2.16kΩ. The output signal on the load is measured with a fast response water resistor divider[9]. The divider with a response time of about 1ns is installed at the end of the transition antenna. The measured waveform is shown in Figure 2.



（a）V_{marx} （b）V_{RL}

Figure 2: Experimental results of the pulser connecting a180Ω resistance dummy load.

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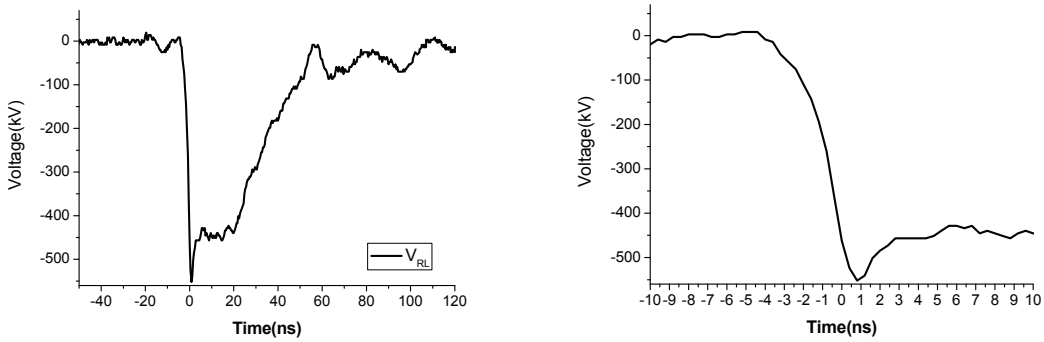

（a）Waveform of V_{RL} （b）Risetime of V_{RL}

Figure 3: Experimental results of the pulser connecting a guided-wave antenna

As can be seen from the Fig. 3, a serious oscillation appears in the trailing edge of the V_{RL} waveform. The reason is not very clear yet, and need to be further researched.

In this study, Marx generator even charged the peaking capacitor up to 700kV. There are no failures happened on the peaking circuit. The voltage on the matching load can reach to 600kV. And the rise time of the voltage waveform is 1.2ns, the FWHM is 32ns.

Test of the pulser with a guided-wave antenna

After the laboratory study, it is necessary to test the pulser further with an actual antenna. A guided-wave antenna grounded with a concentrated load in the terminal is used. The maximum height of the antenna is 10m. The signal input angle of the antenna is 20^0 equated to the flare angle of the antenna transition structure of the pulser. The probes used in this test and their positions are similar with that in the indoor test.

The waveform of antenna V_{RL} is shown in Figure 3. From the figure we can see that the rise time of the voltage waveform on the actual antenna can reach to 2.7ns,and the FWHM is 30ns.

CONCLUSION

A fast pulser with one-stage pulse compression technology is designed. It mainly consists of a low inductance Marx generator, a compact independent-sealed peaking capacitor, an output switch, and a small amount of gas-sealed box. The beauty of the device is simplicity. And the peaking capacitor of this pulser with a tabular structure is prone to matching the conic construction of the guided wave antenna.

The pulser connected a matching resistance dummy load directly can produce a 500kV voltage pulse with a risetime of 1.2ns and a FWHM of 32ns. When it was used to drive a guided-wave antenna which has a maximum height of 10m, the pulser can generate a voltage pulse with a risetime of no more than 2.7ns and a FWHM of 30ns.

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