THE REDESIGN, INSTALLATION OF LIGHT II-A PULSED POWER GENERATOR AND ITS POTENTIAL APPLICATION

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Abstract

Light II-A pulsed power generator was used as a power driver of pumping KrF laser at CIAE. The redesign of Light II-A pulsed power generator is based on the consideration that the machine will consist of one single Marx generator with two different experimental lines, which is presented in this paper. The original experimental line with characteristic impedance of 5 Ω is remained, and a new line of low impedance (about 1.5 Ω) is added to the Marx generator. The structure design and the electric insulation design are introduced. It is also outlined here the manipulation of modeling the dynamic behavior of gas discharge arc as well as the circuit simulation results of the two experimental lines. Meanwhile a brief introduction is given to the potential application of the low impedance line.

INTRODUCTION

The Light II-A pulsed power generator, formerly used to pump KrF laser, is updated now at CIAE for X-pinch research. The update is intended to design a new experimental line consisting of a water insulated PFL, a multichannel gas switch and a low impedance pulse transforming line, with the smallest adjustment of the original experimental line and the Marx generator, so the Light II-A pulsed power generator will be able to alternate from X-pinch mode to laser generator mode quickly.

SIMULATIONS

To verify the design tools and guide the update process, both SPICE based circuit simulation of the original Light II-A pulsed power generator and a PIC-MCC based simulation of the dynamic behaviour of the original laser triggered switch are introduced.

Circuit Simulation

The original Light II-A pulsed power generator could be divided into the following parts [1], a Marx generator consisting of 12 spark gap switches and 24 low inductance capacitors with voltage rating of 100kV and capacitance of 0.1pF, with an erection voltage of 1.8MV and an energy storage of 6.75kJ in maximum; a pulse forming system, which employs a water insulated coaxial transforming line with an impedance of $Z = 7.37\Omega$, is used to form a proper waveform; a laser triggered V/N type gas switch works as the main switch; two paralleled water insulated coaxial transmission lines, with an total equivalent impedance of Z = 5Ω, form the pulse transmission system. Almost all the above parts could be modeled with static components of SPICE based codes except the laser triggered switch, the arc resistance and arc inductance of which are varied with time.

Here, we adopt Eric Worts' Method [2] to simulate the dynamic behavior of the laser triggered switch. Firstly, a kinetic model is developed to show streamer formation and to provide the initial conditions of the following fluid model. Then, a formula based fluid model [3] is used to determine the properties of the arc as current flows through it. The formulas in the fluid model are as follows:

$$R_{arc} = Cd\left[\frac{P_0^{\ 3}}{A^2 i^6}\right]^{1/5} \tag{1}$$

$$r = r_0 + 9.3\times10^{-6}\frac{i^{1/3}t^{1/2}}{\rho_0^{\ 1/6}}[m] \tag{2}$$

Where, R_{arc} is the arc resistance of the spark gap, C is a constant, d is the gap length [m], P_0 is the initial gas pressure [Pa], i is the arc current [A], A is the arc channel cross-sectional area [m^2] $A = \pi r^2$, r is the arc radius, r_0 is the initial radius of arc given by kinetic model, t is the time, ρ_0 is the initial density of background gas [kg/m^3].

The fluid model of the arc and the above static components could be coupled in a SPICE based model by using a SPICE based code SIMPLORER [4], and the circuit scheme of the original Light II-A pulsed power generator is shown in figure 1.

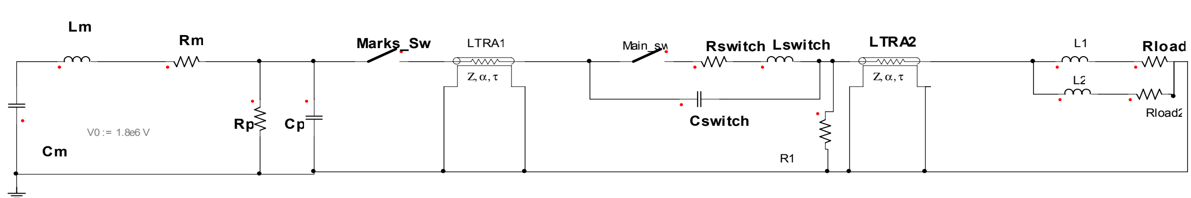

Figure 1: Circuit scheme of the original Light II-A pulsed power generator.

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PIC-MCC Based Simulation

The kinetic model is run on a PIC-MCC code XOOPIC [5]. As the gas filled in the laser triggered switch is Sulfur hexafluoride and the plasma model of XOOPIC code only contains collision cross section data of Hydrogen, Nitrogen and noble gases, we introduce collision cross section data of Sulfur hexafluoride gas given by Ref. [6] to the code.

A scaled-down version of real spark gap, the actual electric field intensity and SF_6 gas at room temperature filled in the gap at a pressure of 2.2 atm are applied in the simulation. The laser triggering is modeled with ionizations in regions that encompassed by the laser beam in fixed rate.

Simulation Results

PIC-MCC simulation shows that the initial radius of arc given by kinetic model is compatible to the width of the laser beam, i.e. r_0 = 200μm . The circuit simulations for new line design will use the above unique r_0 for simplicity, although the gas switch of the new line is different from the original laser triggered gas switch. The voltage wave of the original Light II-A pulsed power generator on the diode given by simulation is shown in figure 2. As a comparison, a typical voltage wave by measurement is shown in figure 3.

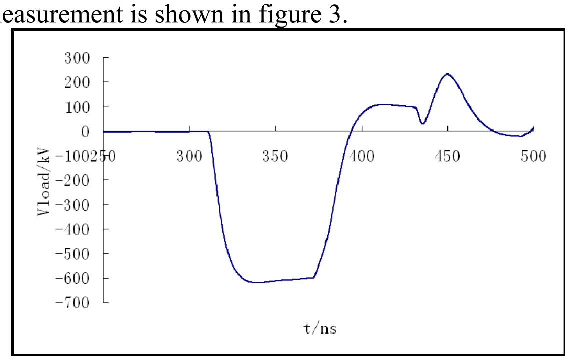

Figure 2: Voltage wave of the original Light II-A pulsed power generator by simulation.

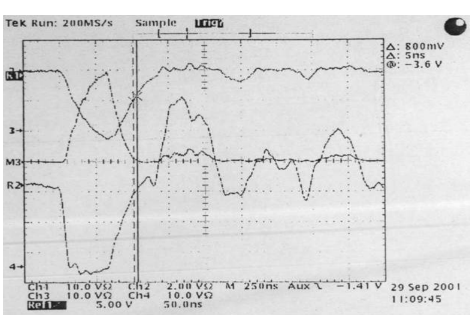

Figure 3: Voltage wave of the original Light II-A pulsed power generator by measurement (see the R2 curve).

Circuit Simulation of New Line

As the impedance of X-pinch load is quite low, the output end of pulse transforming line should have low impedance to match the load. We use a tapered line design with the maximum impedance of 6Ω to match the pulse forming line and the minimum impedance of 1.5Ω to match the load. Circuit simulation shows that the tapered line design can deliver more power to a 1.5Ω resistance load with a faster voltage rise time than the unique impedance design, as is shown in figure 4.

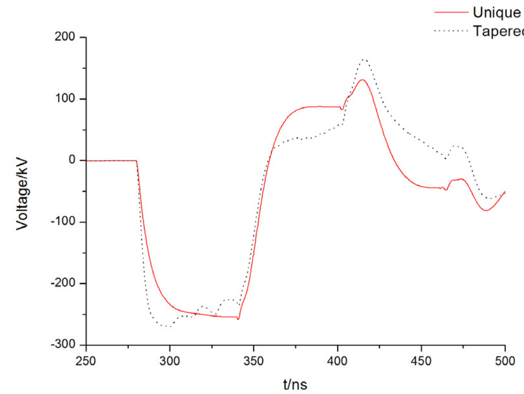

Figure 4: Voltage wave delivered by the new line on a 1.5Ω resistance (Solid: Unique impedance design; Dot: Tapered line design).

REDESIGN CONSIDERATIONS AND INSTALLATION

To leave enough space for the new experimental line, we have to change the shape of the original Marx generator, as shown in figure 5.

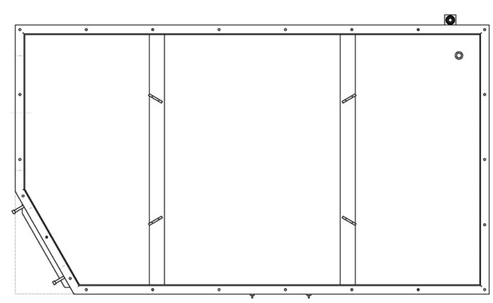

Figure 5: The change of the Marx generator (Top view; Dash: the container of the original Marx generator).

This cause the problem that the distance between the shell of the Marx generator and the capacitors in the output end, which are unfortunately with the highest voltage to the shell of the Marx generator, is too small. So we take out 4 capacitors from the Marx generator and use only 20 capacitors. So, when the Light II-A generator works in laser pumping mode, each capacitor should be charged in a higher voltage than it was before the update. But it will improve the insulation design in the output end of the Marx generator and consequently improve the working stability of the Marx generator significantly.

The redesigned Marx generator and the original experimental line have been installed, as shown in figure 6. The new line is still under fabrication.

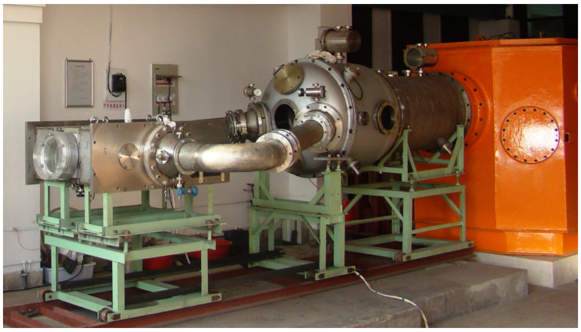

Figure 6: Installation of redesigned Marx generator and original experimental line.

PROTENTIAL USE OF NEW LINE: X-PINCH RESEARCH

Pulsed power generators with current ranging from tens of kilo ampere [7] to mega ampere [8] have been used to drive X-pinch load and many interesting results have been derived from experiments [9]. There are still some unclear issues about the formation dynamics of X-pinch. In our research, we will use 150kA to 200kA current delivered by the new line to drive an X-pinch load in a vacuum chamber.

CONCLUSION

By adding a new line with 1.5Ω impedance and with carefully design, Light II-A pulsed power generator will be able to drive X-pinch load with 150kA to 200kA electric current and will have the capability of alternating from laser pumping mode to X-pinch driver mode within a couple of hours.

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