PREPULSE REDUCTION ON THE FLASH GAMMA GENERATOR GREC.

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Abstract

We use a circuit model for GREC's pulse charge to explain in a simple way the prepulse's origins. Based on this modeling and some computations, we have modified the Marx bank's discharge circuit to reduce the prepulse. This approach has more than halved the prepulse, from 1.5 MV to 0.6 MV.

I. INTRODUCTION

GREC is a multi-megavolt pulsed electric generator doing dense materials radiography. It uses a Marx generator to charge a Blumlein line on a microsecond time scale, which then discharges in less than 100 ns. The resulting pulse reaches a vacuum diode after breaking down a prepulse switch that separates the Blumlein from the diode during the Blumlein charging pulse. The Marx geometry implies a prepulse on the Blumlein. This prepulse couples across the prepulse switch to the vacuum region, where the prepulse is reduced as much as possible with plasma opening switches (POS) in the vacuum close to the diode. In this work we reduce the output prepulse of the Marx before it gets to the POS.

II. PREPULSE ORIGIN

As suggested in Figure 1, a Blumlein pulser has two concentric capacitors (in between three conducting cylinders, Ci and C0), which are charged by a Marx bank on a slow time scale. During this pulse charge there is a the voltage difference between the low voltage side of one capacitor, the inner Blumlein cylinder, and the low voltage side of the other capacitor, the outer Blumlein, or ground. The voltage difference would be zero if the voltage on both capacitors were to increase at exactly the same rate, but this does not happen because of

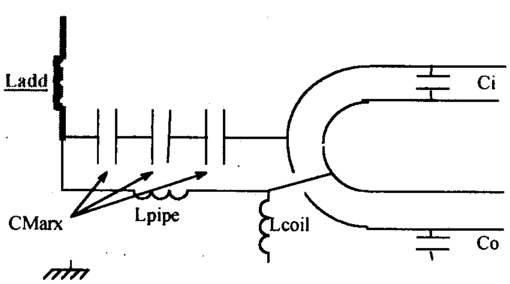

Figure 1. GREC electrical scheme

asymmetries in the pulse charge circuit, hence the prepulse .

One asymmetry comes from the Blumlein geometry. The outer of the three concentric cylinders is also the outside of the machine, including the Marx tank. The inner cylinder is some distance away from this electrical ground: it connects through some finite inductance. The circuit symmetry is restored by connecting the two Blumlein capacitors to the Marx through a center-tapped coil, whose inductances can be selected in such a way that the two Blumlein cylinders charge equally fast. GREC's original charging scheme had this so-called symmetric charging. In a previous upgrade to GREC we modified the symmetric pulse charge circuit to ensure that the Blumlein switch fires at zero prepulse voltage. This could only be done by accepting a 1.5 MV (peak) prepulse, only 5 times smaller than GREC's nominally 8 MV main pulse.

Even with symmetric charging there remains a prepulse from a second asymmetry, the Marx' stray capacitance. The Marx consists of 160 capacitors that are charged in parallel, and discharged in series. In the simplest pulse charge circuit the Marx is represented by a single capacitor that is charged to the appropriate voltage. The Marx' negative side is close to the intermediate Blumlein conductor, but the positive side is so far away that the Marx discharges through a balancing inductor only after a 15 m long pipe, with its own inductance. As a result, the voltage on the back end of the Marx increases, and this couples to the outer Blumlein through the Marx' unintended stray capacitance to ground (the Marx tank).

III. CIRCUIT MODELING

The idea to model the marx discharge circuit comes from of previous works on AURORA [1]. For suggestions on how to reduce the prepulse we have used a simplified representation of the circuit, Figure 2. The Blumlein is modeled as an outer and an inner capacitor (C0 and Ci). The total marx capacitance Cm is arbitrary subdivided into 3 (or sometimes 5) smaller capacitances in series with internal resistance and inductance. The Marx' high voltage end is directly connected through a resistor on the intermediate Blumlein cylinder, which is the high voltage side of both the outer and inner Blumlein capacitors. The other side of C0 is the ground. A pipe connects the marx return current from the inner Blumlein. A coil is between the pipe and the marx wall (Figure 1).

The marx capacitance is initially charged to a high negative voltage, nominally -8 MV. The inner and outer Blumlein charge on the times scales given by $(LC)^{0.5}$,

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where L=Lpipe, C=(Cm.Ci)/(Cm+Ci) for the inner Blumlein circuit, and and L'=(Lcoil+Lpipe), C'=(Cm.C0)/(Cm+C0) for the outer circuit.

In order to eliminate the prepulse, we propose to balance the charging circuit by connecting the marx to ground through an additional inductor Ladd (Figures 1 and 2). We adjust the Ladd value to have the equality such that

(1) : (Ladd.C' = Lpipe.C).

With this equality we get the same charging time scale for inner and outer electrodes.

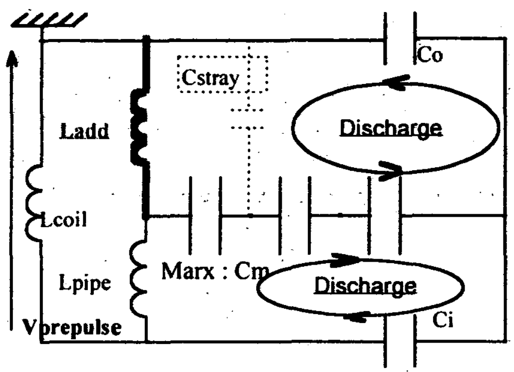

Figure 2. Equivalent circuit

In this analysis, any stray capacitance is neglected. In fact, there is an appreciable stray capacitance from the two sides of the marx, which are large plane surfaces (≈ 35 m2) at 1 m distance from the marx tank walls.

IV. NUMERICAL AND EXPERIMENTAL RESULTS

We can compare the experimental results with 3 PSPICE computations. In the first computation, we determine a value for the pipe's inductance according to its diameter, length and geometry, see reference **[2]**. Then, by iterations, we adjust the inductance until we obtain the same level of prepulse in GREC initial circuit, without an added inductance.

For the second computation, an inductance Ladd is introduced in the circuit that satisfies the expression **(1)**. The prepulse then disappears almost completely in the computations, without marx stray capacitance. For these 2 computations, Figure 3 compares the numerical and experimental prepulses. The pulse charge frequency is reproduced adequately, but there is an apparent phase shift whose circuit representation we have not yet determined.

From the modeling we find the marx stray capacitance (Cs) by matching the computed voltages to the measurements. The final result is in Figure 4. Although the agreement is far from perfect, we consider the agreement satisfactory for the moment because the suggestions developed in the modeling have reduced the prepulse.

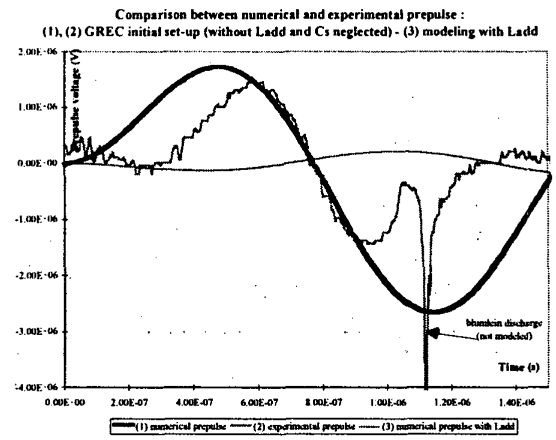

Figure 3. Numerical and experimental prepulse (first and second computations)

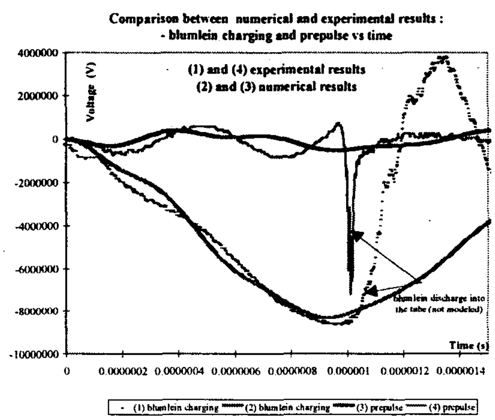

Figure 4. Blumlein charging and prepulse, numerical (with Ladd and Cs) and experimental results (third computations).

GREC's prepulse decreases almost three-fold, from 1.5 MV to 0.6 MV, by connecting the Marx' low voltage end more directly to ground. This is done with by adding a 2 m short piece of 200 mm diameter pipe, with inductance Ladd. The prepulse does not disappear as predicted by the circuit, but it does becomes smaller. Figure 5 compares the prepulse before and after the modification, without and with inductance Ladd.

In fact, the real circuit remains asymmetric. Just for information, we give in the following table the different values used and obtained for the 3 computations corresponding to the results presented in figures 3 and 4 :

Table 1. Components values for computations

Cm	C0	Ci	Lcoil	Lpipe	Ladd	Cs
nF	nF	nF	µH	µH	µH	nF
10	4	2.5	10.4	25	15	0.075

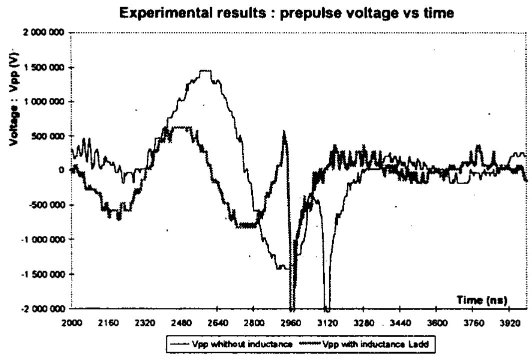

Figure 5. Prepulse voltage before and after modification

Even though it did not disappear, the smaller prepulse on the Blumlein has a beneficial effect on the prepulse transferred downstream. Figure 6 is the voltage behind the prepulse switch, on the tube going from the oil into the vacuum and toward the diode. In the initial set-up we see on the tube a small voltage pulse, with its peak about 160 ns before the main pulse. After adding the inductance in the pulse charge circuit, Figure 7, the smaller pulse disappears and the main voltage pulse on the tube is more reproducible. The final result is an improved operation of GREC where it counts, more repeatable X-rays doses.

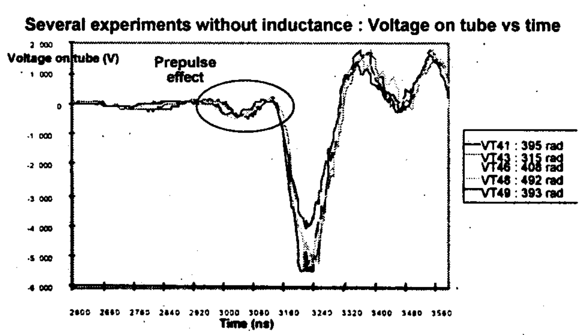

Figure 6. Prepulse effect on the tube voltages

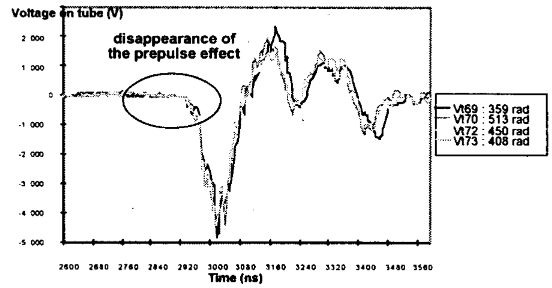

Figure 7. Tube voltages after modification

V. CONCLUSION

SPICE modeling of a simple pulse charge circuit has allowed a better understanding of GREC's operation. Computations suggest a change, which turns out to cut the prepulse in half, or better. The circuit simulations agree qualitatively with this observed trend.

Further reduction in the prepulse may come from balancing the marx stray capacitance in addition to balancing the inductances. However, balancing stray capacitance is not easy to do.

The benefit is that the smaller prepulse on the Blumlein allows the prepulse switches to remain open during the entire pulse charge. The final result is in much better electrical behavior of the diode, and a more reproducible x-ray pulse.

VI. ACKNOWLEDGEMENTS

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VII. REFERENCES

[1] Reproducible pulses from an improved oil switch on AURORA, N. Pereira, N. Gondarenko, 1995 IEEE Pulsed Power, p.846.

[2] Inductance calculations, Working Formulas and Tables, F. W. Grover, Special edition for I.S.A.