

Triggering of Compact Marx Generators

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Abstract— Compact Marx generators have found increasing use in high-power electromagnetic sources for the last few decades [1, 2]. The ease with which simple generators can be assembled often leads people to believe that these are simple devices that should be an easy path to high voltage pulses in the 100's of kV at low energies. Unfortunately, researchers that build these devices often find that they seem to behave in a way that is much different from the simple theory of how a Marx should work. One unusual behavior that is often seen is the very poor or non-existent triggering performance of a compact Marx. In this paper we explore the reasons for this behavior and the additional factors that practitioners in the field of pulsed power must take into account when designing and operating compact Marx generators.

I. INTRODUCTION

A. Basic Operation of a Marx Generator

The basic operation of a Marx generator is dependent on the proper closing of all of the spark gap switches within a very short time in a process known as erection of the Marx. One or more of the spark gap switches will be triggered by an external pulse and the remaining switches are closed by the overvoltage created by the closing of the previous switches. In an ideal case, this would result in sequential operation of the switches and the expected operation of the Marx would be achieved.

B. Compact Marx Generators

In relatively large, open-air Marx generators, the ideal model of operation can often be assumed without any real impact on the design. However, when a Marx is made very compact and low-energy the stray capacitances of the spark gaps and other conductive components become an appreciable fraction of the value of the Marx capacitors. This fundamentally changes the operation from that of the ideal model. The initial design is made more complicated by the difficulty in estimating stray capacitance.

II. ERECTION OF A COMPACT MARX

In compact Marx generators, the stray capacitances that affect the erection process are primarily the gap capacitance C_g , the inter-stage stray capacitance C_i , and the stage-to-ground stray capacitance C_s as shown in Fig. 1.[3]

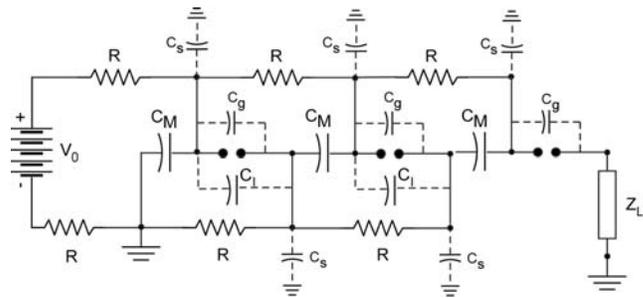


Figure 1. Three stage compact Marx equivalent circuit.

Note that the usual plate-style construction of compact Marx generators results in C_i being in parallel with C_g so these sum to a larger effective capacitance.

When the first switch in the Marx closes, the voltage on one side of the next switch is driven up. This change in the voltage on C_g necessitates a displacement current through the switch. The best sink for this current is C_s . If C_s is not much greater than $C_g + C_i$, then the current must sink through the series impedance of the load, the remaining unfired switches, and the Marx capacitors. This creates voltage drops across the load and each switch leading to a significant reduction in overvoltage on the second switch. Unfortunately, reducing the size of the Marx drives C_g and C_i up while C_s either stays the same or decreases. The high (often open circuit) impedance of HPRF loads prior to reaching full voltage also exacerbates this problem.

Addressing this issue requires that the transient impedance from each stage to ground be minimized. A common method of accomplishing this – surrounding the Marx with a grounded metal can has multiple benefits [4] but results in insulation issues that can be difficult to overcome. Other methods, including introducing artificial back-coupling capacitances can be implemented at the expense of extra complexity and size. Here, the factors that influence the Marx erection process and its relation to triggering are examined.

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