MARX GENERATOR

Definition

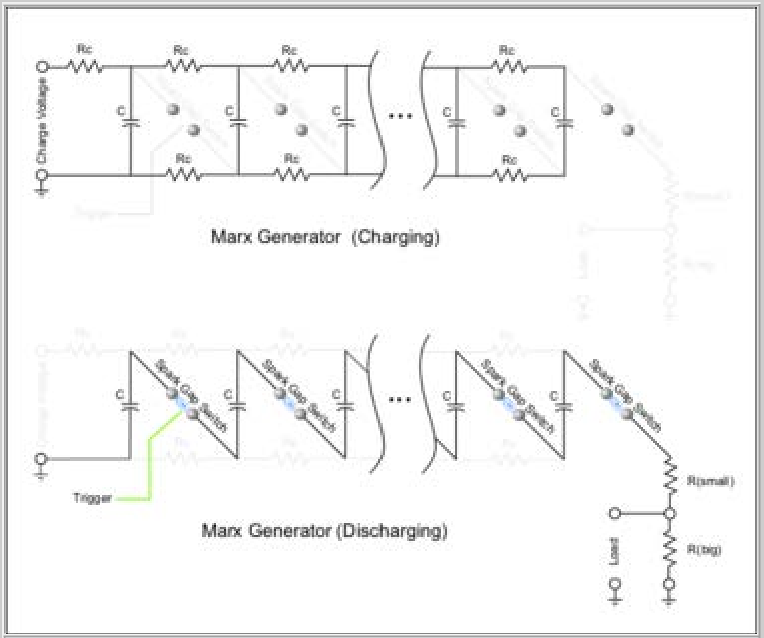
A **Marx generator** is a type of electrical circuit whose purpose is to generate a high-voltage pulse by a number of capacitors that are charged in parallel and then connected in series by spark gap switches.

Basics

A **Marx generator** is a type of electrical circuit first described by Erwin Otto Marx in 1924 whose purpose is to generate a high-voltage pulse. It is extensively used for simulating the effects of lightning during high voltage and aviation equipment testing. A bank of 36 Marx generators is used by Sandia National Laboratories to generate X-rays in their Z Machine. It can also be used as an ignition switch for thermonuclear devices.

Principle

A number of capacitors are charged in parallel to a given voltage, V, and then connected in series by spark gap switches, ideally producing a voltage of V multiplied by the number, n, of capacitors (or stages). Due to various practical constraints, the output voltage is usually somewhat less than n×V.



Marx generator diagrams; Although the left capacitor has the greatest charge rate, the generator is typically allowed to charge for a long period of time, and all capacitors eventually reach the same charge voltage.

Optimization

Proper performance depends upon selection of capacitor and the timing of the discharge. Switching times can be improved by doping of the electrodes with radioactive isotopes caesium 137 or nickel 63, and by orienting the spark gaps so that ultraviolet light from a firing spark gap switch illuminates the remaining open spark gaps. Insulation of the high voltages produced is often accomplished by immersing the Marx generator in transformer oil or a high pressure electronegative gas such as sulfur hexafluoride (SF6).

Note that the less resistance there is between the capacitor and the charging power supply, the faster it will charge. Thus, in this design, those closer to the power supply will charge quicker than those farther away.

If the generator is allowed to charge long enough, all capacitors will attain the same voltage.

In the ideal case, the closing of the switch closest to the charging power supply applies a voltage 2V to the second switch. This switch will then close, applying a voltage 3V to the third switch. This switch will then close, resulting in a cascade down the generator that produces nV at the generator output (again, only in the ideal case).

The first switch may be allowed to spontaneously break down (sometimes called a self break) during charging if the absolute timing of the output pulse is unimportant. However, it is usually intentionally triggered once all the capacitors in the Marx bank have reached full charge, either by reducing the gap distance, by pulsing an additional trigger electrode (such as a Trigatron), by ionising the air in the gap using a pulsed laser, or by reducing the air pressure within the gap.

The charging resistors, Rc, need to be properly sized for both charging and discharging. They are sometimes replaced with inductors for improved efficiency and faster charging. In many generators the resistors are made from plastic or glass tubing filled with dilute copper sulfate solution. These liquid resistors overcome many of the problems experienced by more-conventional solid resistive materials, which have a tendency to lower their resistance over time under high voltage conditions.

Stage variants

Avalanche diodes can replace the spark gap for stage voltages less than 500 volts. The charge carriers easily leave the electrodes, so no extra ionisation is needed and jitter is low. The diodes also have a longer lifetime than spark gaps.

A speedy switching device is an NPN avalanche transistor fitted with a coil between base and emitter. The transistor is initially switched off and about 300 volts exists across its collector-base junction. This voltage is high enough that a charge carrier in this region can create more carriers by impact ionisation, but the probability is too low to form a proper avalanche; instead a somewhat noisy leakage current flows. When the preceding stage switches, the emitter-base junction is pushed into forward bias and the collector-base junction enters full avalanche mode, so charge carriers injected into the collector-base region multiply in a chain reaction. Once the Marx generator has completely fired, voltages everywhere drop, each switch avalanche stops, its matched coil puts its base-emitter junction into reverse bias, and the low static field allows remaining charge carriers to drain out of its collector-base junction.

Applications

One application is so-called boxcar switching of a Pockels cell. Four Marx generators are used, each of the two electrodes of the Pockels cell being connected to a positive pulse generator and a negative pulse generator. Two generators of opposite polarity, one on each electrode, are first fired to charge the Pockels cell into one polarity. This will also partly charge the other two generators but not trigger them, because they have been only partly charged beforehand. Leakage through the Marx resistors needs to be compensated by a small bias current through the generator. At the trailing edge of the boxcar, the two other generators are fired to "reverse" the cell.

Marx generators are used to provide high-voltage pulses for the testing of insulation of electrical apparatus such as large power transformers, or insulators used for supporting power transmission lines. Voltages applied may exceed 2 million volts for high-voltage apparatus.

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