Integrated System of a Mini-Marx Generator Charged by a Cockcroft-Walton Voltage Multiplier

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Abstract: *A Marx generator generates a high-voltage pulse by charging lots of capacitors in parallel, then suddenly connecting them in series. In principles, a comparatively lower voltage DC power supply can be used for the charging to achieve the desired high voltage. However, a moderate DC high-voltage power supply is still quite expensive and bulky but not in full-time charging. In this work, a mini-Marx generator powered by a Cockcroft-Walton (CW) voltage multiplier has been proposed to form a more efficient but affordable choice of pulsed high-voltage power sources. For generating a high voltage in a range of 70-100 kV, the mini-Marx generator consists of 8 stages. Therefore, a CW multiplier operating up to 10-15 kV is required. For demonstration, a 22-stage CW multiplier with an AC supply voltage of 220V at 60 Hz is chosen so that it can be driven by household electricity to generate a DC voltage of over 13 kV to charge the mini-Marx generator. Numerical simulations using PSpice have been performed for validating the concept. A prototype is developed. After setting a suitable time-controlled switch for releasing CW multiplier and a trigger for the spark gaps of the mini-Marx generator, the preliminary simulation results predicting a pulsed open-circuit voltage up to 85 kV from the mini-Marx generator can be achieved while being charged by the CW generator operating at 11 kV. Detailed simulation and experimental results will be presented.*

Keywords: *Cockcroft-Walton multiplier; mini-Marx generator; PSpice; high-voltage.*

Introduction

A Cockcroft-Walton (CW) voltage multiplier is a multilevel voltage multiplier that is often used in many ways due to its components are only diodes and capacitors. This voltage multiplier converts the AC voltage at the input side to a higher DC voltage. Some examples of the use of the CW voltage multiplier circuit in daily life are in X-Ray, electron microscope, accelerator, and so on. The design of CW voltage multiplier begins with determining the required DC output voltage value and knowing the available AC input voltage value. This circuit can be extended to any number of stages. The no-load output voltage is twice the peak input voltage multiplied by the number of stages N. The no-load output voltage is defined as

$$V_{out} = 2NV_p.$$

A Marx generator is an electrical circuit whose purpose is to generate a high-voltage pulse from a low-voltage DC supply. The circuit generates a high-voltage pulse by charging numbers of capacitors in parallel, then suddenly connecting them in series to deliver a high-voltage pulse to the load that is theoretically N×V, where N is the stage of Marx generator and V is the charging voltage. Marx generator can simulate lightning and operating over-voltage processes. Therefore, it is often used in high-energy physics experiments such as insulation shock withstand voltage and dielectric shock breakdown and discharge.

In this work, a mini-Marx generator powered by a CW voltage multiplier has been simulated by PSpice simulations. The 22-stages PSpice model has been built and verified by comparing the output voltage value with theoretical value, giving good agreement.

Simulation model and method

The PSpice model of 8-stage Marx generator powered by a 22-stage CW voltage multiplier is shown in Fig. 1. In this model, we first charge CW voltage multiplier with household electricity (220V and 60Hz AC voltage). We turn off the switch connecting CW voltage multiplier and Marx generator after first 100 s of the charging time of the simulation to make sure that all the capacitors of CW voltage multiplier have been fully charged. Also, the CW voltage multiplier can provide stable DC voltage power to Marx generator. And in the Marx generator part, the spark gaps play an important role in the operation. Here, we used a time-controlled switch for modeling a spark gap in our PSpice simulation. We close the first switch 0.005 s after closing the switch connecting the CW voltage multiplier and the Marx generator in the simulation to make sure that all the capacitors of Marx generator have been fully charged. The time delay between adjacent switches is about 0.6 ns. A transient analysis is used. The total simulation time is 105 s for all simulation cases.

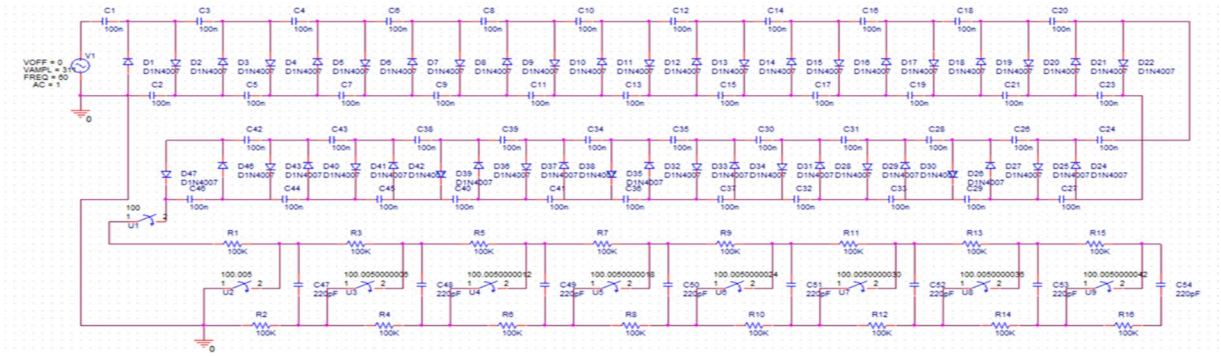

Figure 1. PSpice model of the 8-stages Marx generator powered by the 22-stages CW voltage multiplier.

Results and discussion

The voltage waveform of the CW voltage multiplier is shown in Fig. 2. It is found that when the CW voltage multiplier is charged for 100s, the output DC voltage can exceed 13 kV, giving good agreement with the theoretical prediction. After the connecting switch is closed, the CW voltage multiplier starts charging the Marx generator, causing the voltage to drop. The voltage waveforms of each stage charging capacitor in Marx generator are shown in Fig. 3. Because the time-controlled switches are closed for different times, the voltage waveform of each capacitor varies. But in the end, all of them can be charged to about 11 kV. The time to a full charge for all stages can be seen. Fig. 4 shows the output voltage of the Marx generator without a load (open circuit) and the output voltage can reach 85 kV. As shown in Fig. 5, the real circuit model has been built and is under test at NCKU.

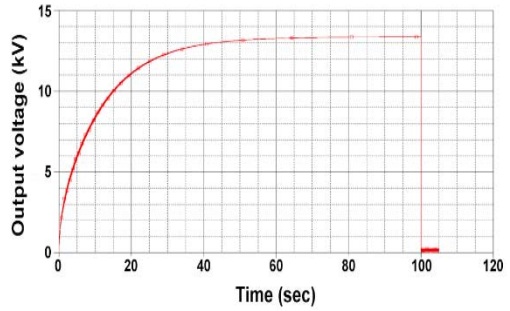

Figure 2. Voltage waveform of the CW multiplier.

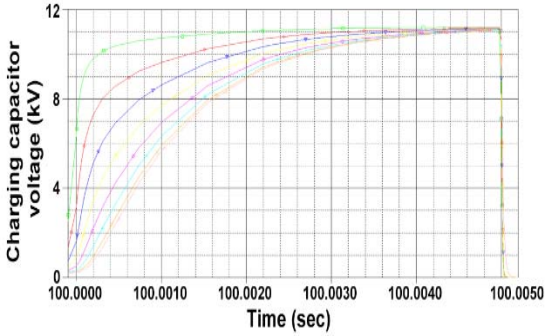

Figure 3. Voltage waveforms of Marx generator of each stage charging capacitor (stage 1 to 8 from top to bottom).

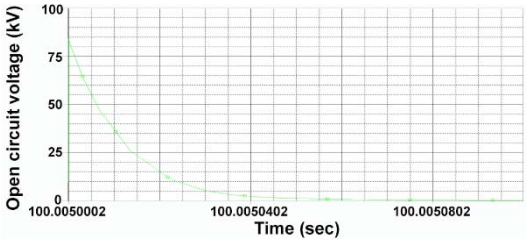

Figure 4. Output voltage waveform of the Marx generator without a load.

Figure 5. Prototype of the 8-stage Marx generator powered by the 22-stage CW voltage multiplier.

Conclusion

The mini-Marx generator powered by a CW voltage multiplier is investigated using PSpice simulations. The PSpice model of the CW voltage multiplier and Marx generator have been successfully built and verified by comparing with the theoretical prediction. Charging the 22-stage CW voltage multiplier by household electricity can reach an output DC voltage of 13 kV. The CW voltage multiplier can be used to charge each stage of Marx generator to 11 kV. Finally, this mini 8-stage Marx generator can generate 85 kV of open circuit voltage. The integrated system can be a more efficient, compact, while affordable high voltage power source.

References

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