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To cite this article: Dalya H. Al-Mamoori *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **518** 042019

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Generating High Voltage DC with Cockcroft-Walton Voltage Multiplier for Testing Locally Assemble Electric Field Sensor

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Abstract. This paper describes the construction of a high voltage DC generator using single-phase transformer and Cockcroft-Walton voltage multiplier. The aim is to simulate high voltage DC for simulating electric field produced before a lightning strike near the ground. Lower AC voltage is step up to high AC voltage using a neon transformer. The AC voltage is then converted into high DC voltage using variable stages of Cockcroft-Walton voltage multiplier. The generator HVDC is connected to the adjustable parallel plate to ground. Variable stages of Cockcroft-Walton voltage multiplier produce high voltage magnitude proportional to each stage of it. The electric field generated from high voltage DC can also be varied depending on the distance between DC output plate and ground. The application of high voltage DC in generating electric field useful in testing locally assembled Electric Field Sensor.

Keywords: Lightning; AC to DC converter; Cockcroft-Walton voltage multiplier; Electric Field Sensor.

1. Introduction

Lightning happens when there is an opposite polarity of electrical charges formed on the cloud and at a point in the ground, attracted towards each other. There are two common types of lightning that are I-C lightning (intra-cloud) and C-G lightning (cloud-ground) [1-3].

Static electric field produces near the ground before a lightning strike. The strength of each lightning stroke depending on the electric field intensity produced near the ground [4]. During bad weather, the intensity of lightning measured from ground to the point below thundercloud might surpass 10,000 V/m. existing of vertical object interrupts the distribution of positive charges on the ground. The charges happen to cover the top of the object which causes an intense electric point at that point. Fort et al. [5] proposed an atmospheric electric field measurement device. This device functions by periodically exposed a sensing plate to measure electrostatic field changes in the event of lightning discharges. The measurement which is recorded in the form of alternating current is later converted into voltage [6]. The output voltage is analogs to the atmospheric electric field strength.

Atmospheric electric field intensity can be artificially produced in the laboratory area. The electric field can be simulated by generating high voltage DC. Lower AC source is stepping up to high voltage DC through a step-up transformer and Cockcroft-Walton voltage multiplier. Providing the advantage of high voltage ratio, low voltage stress on the diodes and capacitors, compactness, and low cost the



conventional Cockcroft-Walton voltage multiplier is a popular option among high voltage DC applications [7]. The Cockcroft-Walton voltage multiplier which is developed in the 1930s is widely used in high voltage-low current applications such as power supplies, X-ray units, TV sets, CRTs tubes, Oscilloscope, and Photomultiplier tubes are used in nuclear industry for detection of radiation [8-11].

Dwivedi et al. [7] proposed a low-cost DC high voltage generator with 60kV output using Cockcroft-Walton voltage multiplier. Voltage value increases as it goes through each stage of the voltage multiplier. Limited design criterion was proposed including capacitor and frequency selection as well as forward voltage and forward current. The development is useful for field testing as suggested by Dwivedi et al. [7].

2.Theory

High voltage DC can be generated by stepping up AC power source through a step-up transformer and Cockcroft-Walton voltage multiplier. The application of Cockcroft-Walton voltage multiplier depends on few criteria such as a number of stages, frequency supply as well as capacitor value. Figure 1 below shows the Cockcroft-Walton voltage multiplier circuit.

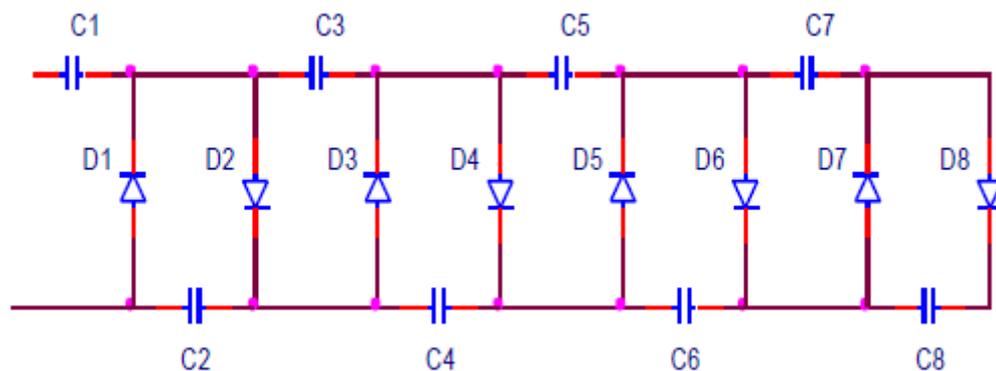


Figure 1. Cockcroft-Walton voltage multiplier circuit.

The output voltage produced from this voltage multiplier circuit depends on the number of stages that is $2nV_{max}$ where n is the number of the stage while V_{max} represented at C1. The voltage at C2, C4, C6, and C8 will be $2V_{max}$, $4V_{max}$, $6V_{max}$, and $8V_{max}$, respectively.

Frequency and capacitor value relate to each other in determining the circuit performance. 50Hz of frequency requires $\approx 0.1-200 \mu\text{F}$ capacitor. On the other hand, a higher frequency such as 1 kHz requires capacitance in the range of $\approx 0.02-0.06 \mu\text{F}$. Figure 2 below shows the connection of high voltage DC generation to simulate electric field.

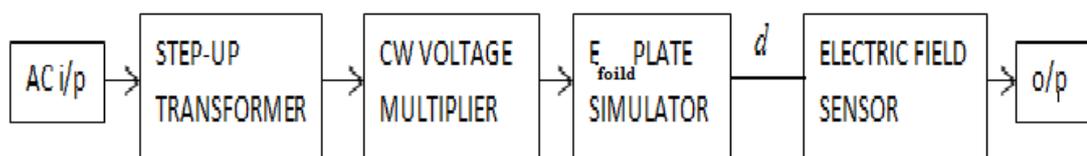


Figure 2. Block diagram of electric field simulation.

Electric field intensity is obtained by dividing HV output (produced at electric field plate simulator) with the distance between Electric Field plate simulator and Electric Field Sensor. The output high voltage DC is correlated with the output voltage measured by the Electric Field Sensor. Thus, the electric field intensity measured in the laboratory area is approximately the same with the atmospheric electric field produced before a lightning strike.

3. Simulation

The simulation work has been done using PSpice software. Figure 3 below shows a schematic diagram of high voltage DC with multiple stages of Cockcroft-Walton voltage multiplier.

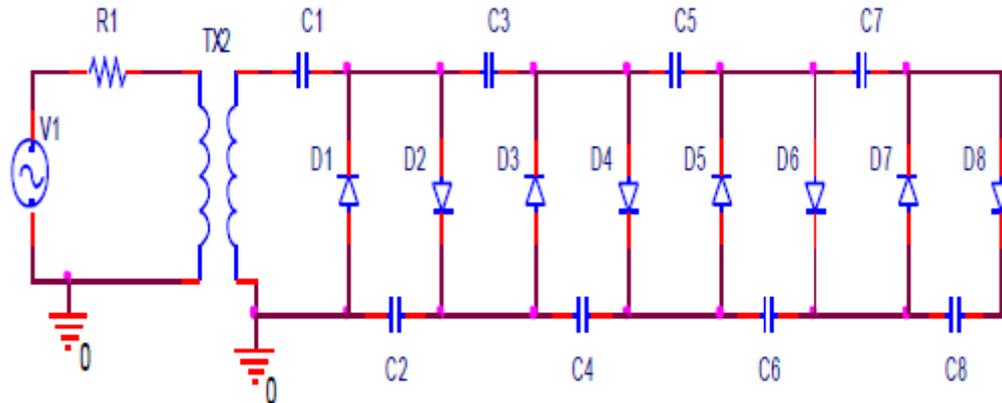


Figure 3. Schematic diagram of Cockcroft-Walton voltage multiplier.

240Vp-p of AC source and 50Hz of frequency are used for simulation. The capacitor value in the design is directly proportional to the frequency. It must withstand the maximum voltage flows through each stage of the voltage multiplier. With the frequency value of 50 Hz, the capacitor with a value of 0.1 μF is selected. Figures 4 to 6 below show the simulated results for each stage of Cockcroft-Walton voltage multiplier.

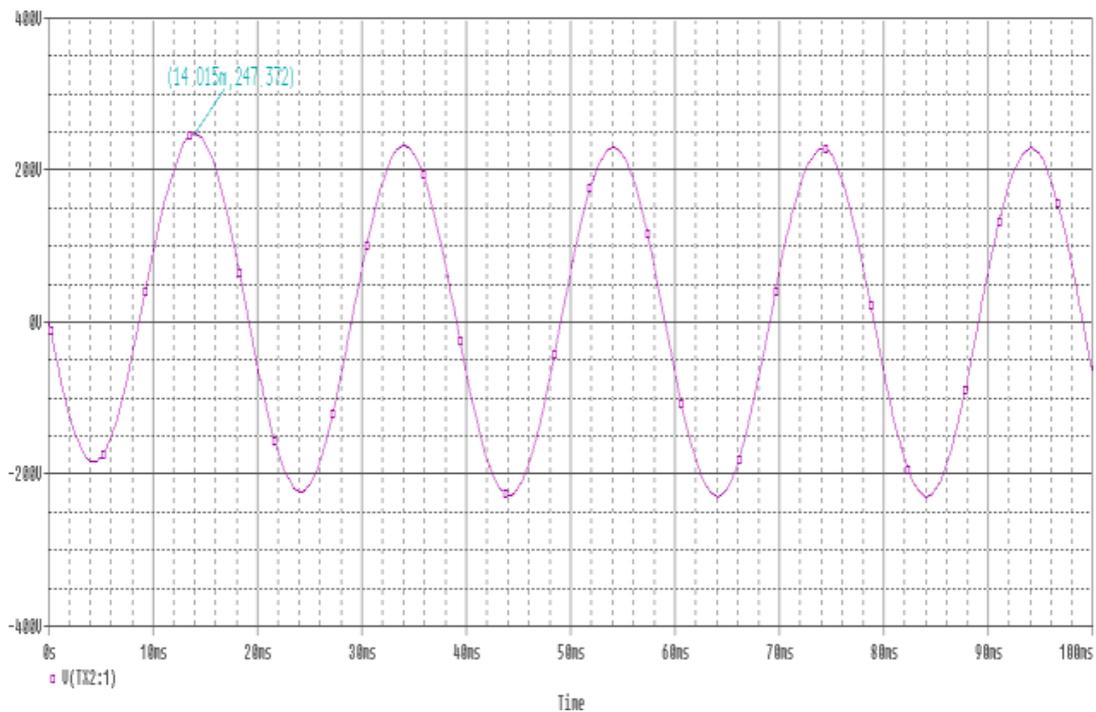


Figure 4. Transformer primary voltage.

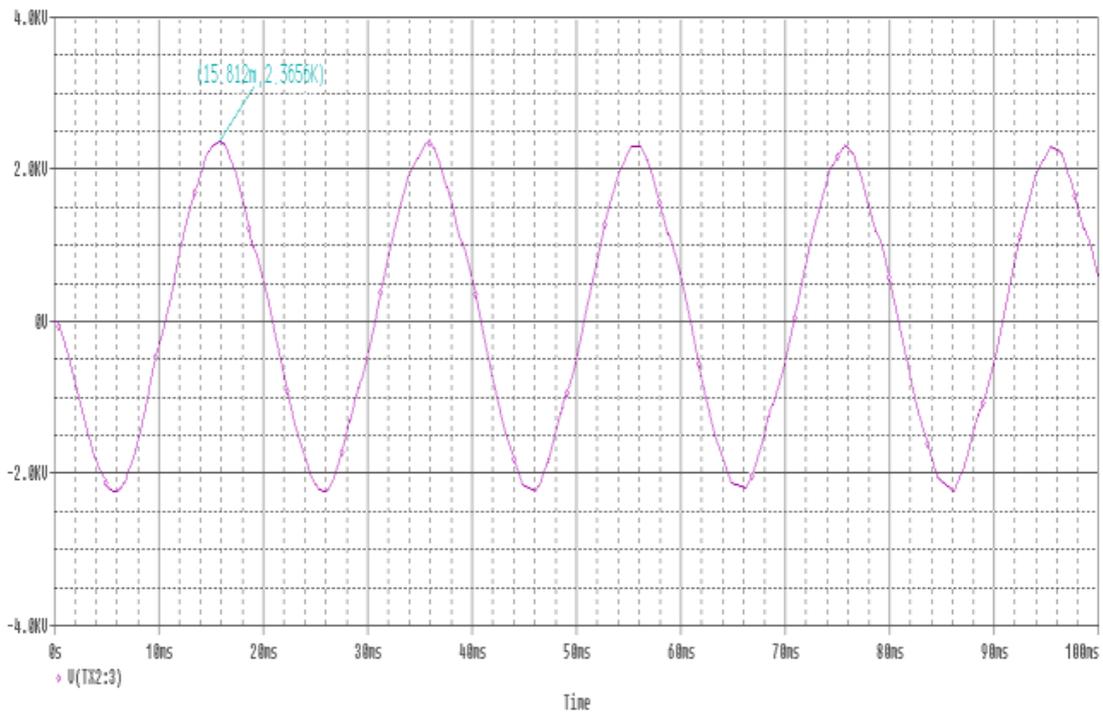


Figure 5. Transformer secondary voltage.

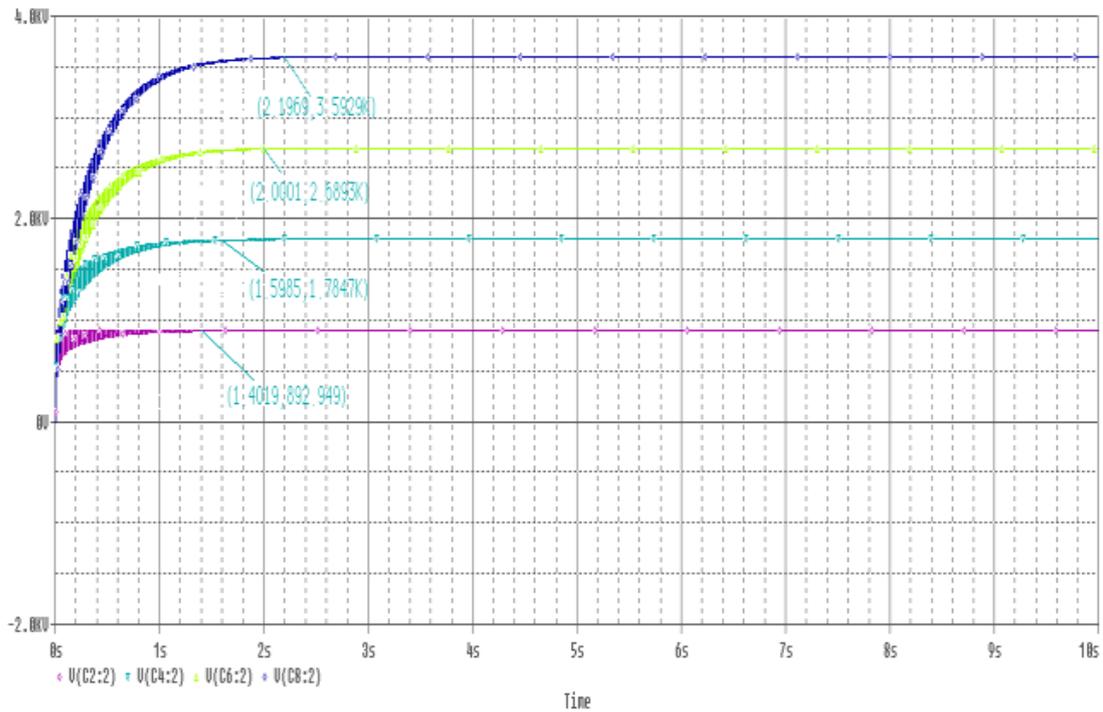


Figure 6. DC output voltage of stage 2, 4 and 6.

The output voltage produced from Cockcroft-Walton voltage multiplier is used to determining the electric field intensity. The electric field intensity is presented in Figure 7 by dividing the DC output voltage with d .

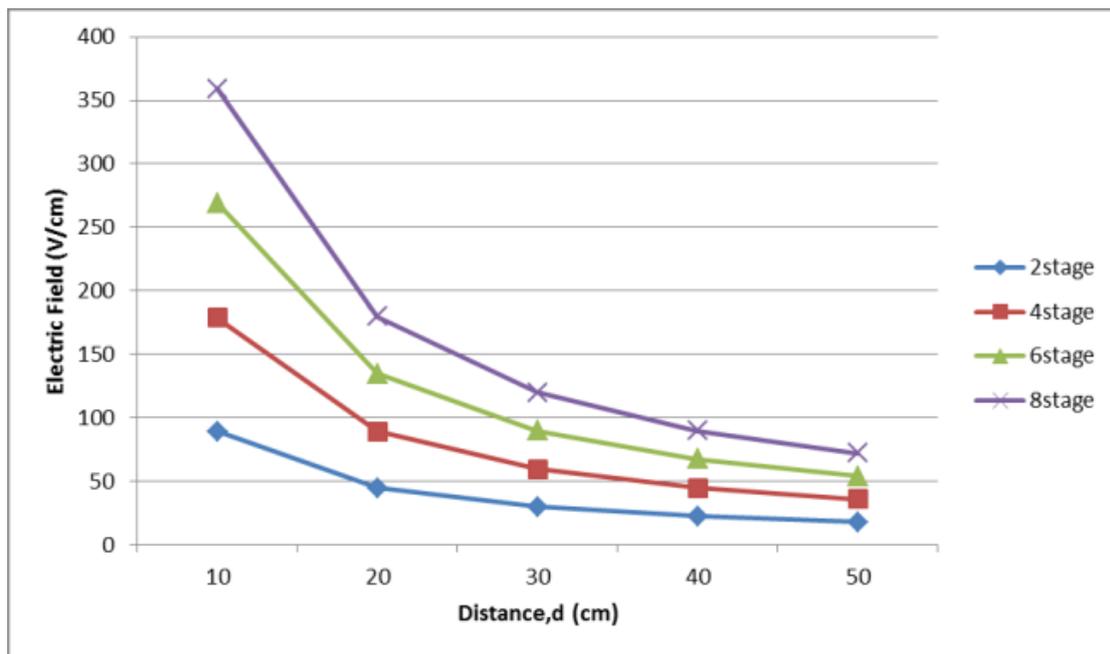


Figure 7. Electric field intensity

Results clarify that the electric field strength is inversely proportional to the distance between electric field plate simulator and Electric Field Sensor. This electric field intensity is proportional with the atmosphere electric field strength measured by the Electric Field Sensor.

4. Conclusion

High voltage DC with Cockcroft-Walton voltage multiplier has been used in generating an electric field in the pre-event of lightning discharges. Cockcroft-Walton voltage multiplier helps in boosting the output DC voltage from a low AC power source. Electric field produced before a lightning strike can be determined by dividing the DC voltage to the distance between electric field plate simulator and Electric Field Sensor. The simulated electric field can be used in testing locally assembled Electric Field Sensor. The high voltage DC output must be correlated with the output voltage measured by the Electric Field Sensor.

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