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Compact Marx Generator using Cockroft-Walton Voltage Multipier Circuit

Mr. Hitesh Murkute[1], Mr. Animesh Mandal[2], Mr. Atif Ali[3]
Corresponding author:- Hitesh_murkute@rediffmail.com
Asst. Professor, Dept. of EE, GNIET, Nagpur, Maharashtra, India[1]
UG Student, Dept. of EE, GNIET, Nagpur, Maharashtra, India[2,3]

Abstract **-** This paper reports a high voltage impulse generators. Generation of variable outputs impulse generator can be designed by combination of Cockcroft Walton voltage multiplier and Marx generator which can produce different high voltages. It is a portable device for field. The Marx generator is the simplest and most widely used high voltage pulse generation device.

In order that equipment designed to be used on high voltage lines, and others, be able to withstand surges caused in them during operation, it is necessary to test these equipment with voltages of the form likely to be met in service. The apparatus which produces the required voltages is the impulse generator. In high voltage engineering, an impulse voltage is normally a unidirectional voltage which rises quickly without appreciable oscillations, to a peak value and then falls less rapidly to zero. A full impulse wave is one which develops its complete waveshape without flashover or puncture, whereas a chopped wave is one in which flash-over occurs causing the voltage to fall extremely rapidly. The rapid fall may have a very severe effect on power system equipment. The lightning waveform, is a unidirectional impulse of nearly double exponential in shape. That is, it can be represented by the difference of two equal magnitude exponentially decaying waveforms. In generating such waveforms experimentally, small oscillations are tolerated.

Keywords: *High Voltage Power Supply, Cockcroft Walton voltage multiplier, Marx Generator, HV Generator.*

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I. INTRODUCTION

Lightning is a natural phenomenon which behaves very erratically. Natural lightning originates due to partition of electrical negative and positive charges by processes in atmospheric. When the charge gets increase in numbers, then air medium between the negative and positive areas breaks down in form of a massive spark, or a charged area breaks down to surface of ground (cloud to ground stroke)

In the present scenario, to reduce the gap between demand and generation, power systems reliability is of utmost importance. Power system component subjected by Impulse Voltages and are momentary. A **Marx generator** is an electrical circuit first described by Erwin Otto Marx in 1924.Its principle is to generate a high voltage pulse using a number of capacitors in parallel to charge up during the on time and then connected in series to develop higher voltage impuse during the off period. This principle is used to generate voltages in the range of KV's in real-time for testing the insulation of the electronic appliances like transformers and the insulation of the power carrying lines.

The input of Marx Generator is designed by the Cockcroft Walton voltage multiplier.

II. DESIGN

1) Block diagram

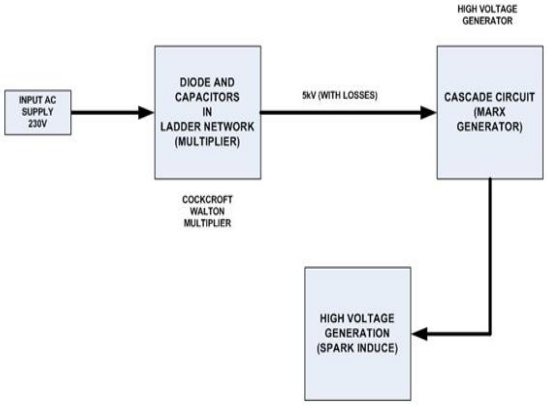

Figure-1 Block diagram.

2) Design of Cockcroft Walton Voltage multiplier circuit

The CW is a voltage multiplier that converts AC or pulsing DC electrical power from a low voltage level to a higher DC voltage level. It is made up of a voltage multiplier ladder network of capacitors and diodes to generate high voltages. Unlike transformers, this method eliminates the requirement for the heavy core and the bulk of insulation/potting required. Using only capacitors and diodes, these voltage multipliers can step up relatively low voltages to extremely high values, while at the same time being far lighter and

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19 – 22

cheaper than transformers. The biggest advantage of such circuits is that the voltage across each stage of the cascade is equal to only twice the peak input voltage in a half-wave rectifier. In a full-wave rectifier it is three times the input voltage. It has the advantage of requiring relatively low-cost components and being easy to insulate. One can also tap the output from any stage, like in a multitapped transformer.[1]

To understand the circuit operation, see the diagram of the two-stage version at right. Assume the circuit is powered by an alternating voltage $\boldsymbol{V_i}$ with a peak value of V_p. After the input voltage is turned on

- When the input voltage $\boldsymbol{V_i}$ reaches its negative peak $-V_p$, current flows through diode *D1* to charge capacitor *C1* to a voltage of V_p.
- When $\boldsymbol{V_i}$ reverses polarity and reaches its positive peak $+V_p$, it adds to the capacitor's voltage to produce a voltage of $2V_p$ on *C1*s right-hand plate. Since *D1* is reverse-biased, current flows from *C1* through diode *D2*, charging capacitor *C2* to a voltage of $2V_p$.
- When $\boldsymbol{V_i}$ reverses polarity again, current from *C2* flows through diode *D3*, charging capacitor *C3* also to a voltage of $2V_p$.
- When $\boldsymbol{V_i}$ reverses polarity again, current from *C3* flows through diode *D4*, charging capacitor *C4* also to a voltage of $2V_p$.

With each change in input polarity, current flows up the "stack" of capacitors through the diodes, until they are all charged. All the capacitors are charged to a voltage of $2V_p$, except for *C1*, which is charged to V_p. The key to the voltage multiplication is that while the capacitors are charged in parallel, they are connected to the load in series. Since *C2* and *C4* are in series between the output and ground, the total output voltage (under no-load conditions) is $\boldsymbol{V_o} = 4V_p$.[1]

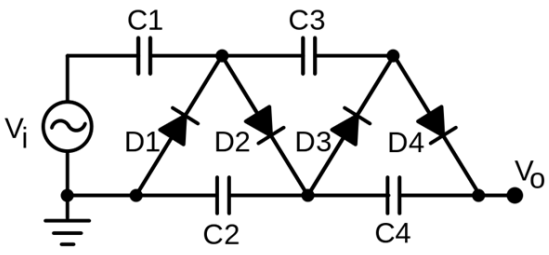

Figure-2 circuit diagram of Cockcroft Walton voltage multiplier.[1]

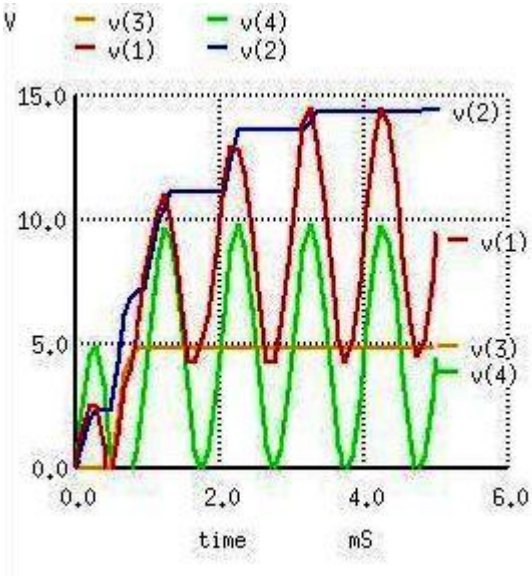

Figure-3 Output wave form[1]

3) Design Of Marx Generator

The Marx generator (proposed by **Prof. Erwin Marx** in 1923 at the Technical University of Braunschweig, Germany) works on the principle of charging several capacitors in parallel and discharging them in series so that voltages add up. The current is limited by the ability of the stage capacitors. Fig-4 shows a four stage Marx generator.[2]

The capacitors get charged through the charging resistors, RC. After reaching the desired voltage the first spark gap is self triggered. However, if controlled triggering is required, the first gap is usually triggered by an external means using a three electrode gap or Trigatron gap based triggering scheme. Twice the voltage (due to two capacitors coming in series) appears across the second spark gap, and breakdown occurs in that gap.

The ideal no-load output voltage across the load is equal to n*V, where n is number of stages and V is the stage charging voltage. R1 and R2 are wave shaping resistors to control the front time and tail time of the impulse voltage waveform.

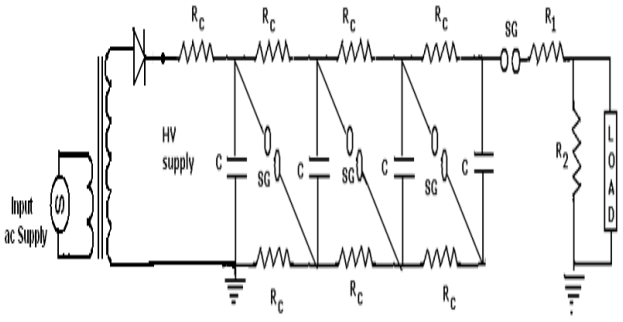

Figure-4 Circuit diagram of MARX Generator[2]

 ISSN: 2454-4248
19 – 22

III. PRACTICAL SETUP

In this experiment we have used two circuits,

1) Cockcroft Walton Voltage Multiplier
2) Marx Generator

In Cockcroft Walton Voltage Multiplier Circuit we have used two components which are as follows and arranged them as per circuit diagram.

1) Film Capacitors, 1uf, 400V
2) Diodes (IN5408), 1KV, 3A

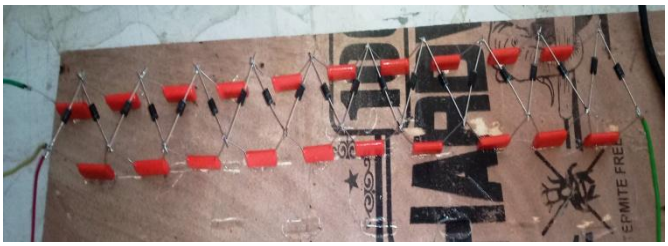

Figure-5 Experimental setup of CW multiplier

In Marx Generator circuit we have used two components which are as follows and arranged them as per the circuit diagram.

1) Ceramic capacitor 1nF,6KV
2) Resistor carbon film 1MΩ,2W

Figure-6 Arrangement of MARX ciruit

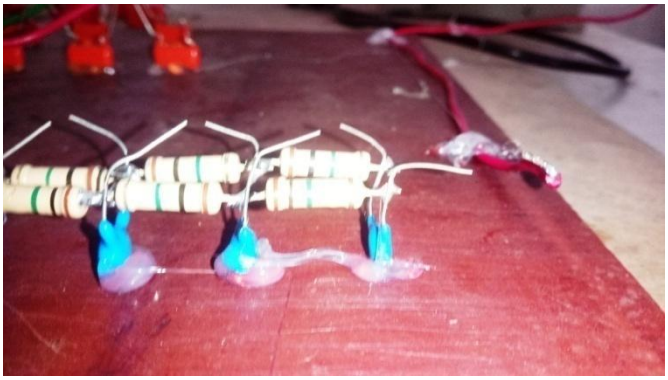

Figure-7 Spark Gap arrangement

Figure-8 Complete setup

IV. RESULT

We have tested the circuit with supply voltage of 180-220V and have successfully obtained the output.

V. CONCLUSION

Marx generators are effective systems for efficient voltage multiplication. For short pulse generation the Marx should operate near its critical damping due to a balance between voltage efficiency and overshoot. The transient wave erection Marx should be used where fast risetimes are critical.

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ISSN: 2454-4248
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