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Article

Marx Multistage Impulse Generator

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ABSTRACT

This generator generates lightning impulse voltages of upto 45 KV. This paper defines the progress of a cost effective and effortlessly portable compact 10 stages Marx Generator proficient of manufacturing lightning impulses voltage up to 45kV. In adding, three different investigational circuits of HV DC provisions have been made. The uppermost output was 15 kV DC which was occupied as the main supply for the Marx generator circuit. This generator can be castoff by small scale productions and theoretical institutions to prove impulse voltages and also to achieve testing on insulators of lower rating in laboratory. A total of 10 stages of both replicated, new Marx impulse generator circuit was considered and the impulse waves were documented. In this work, the assessment in terms of magnitude of the investigational and simulated 10 stages Marx generator circuit has been carried out as well as its descriptive curve has been drawn. These results have long-established the strength of the planned technique and they were in close arrangement.

Keywords: Generator, High Voltage, Switching Impulse, Impulse Wave, Marx Generator

Introduction

Most of the high voltage equipments such as power transformers, surge arresters, circuit breakers, isolators and high tension transmission line towers are placed in transmission substations. As these equipments are very costly and important for maintaining continuity of power supply, there safety should be the major priority for an electrical engineer. These equipment must tolerate not only the rated voltage which corresponds to the highest voltage of a particular system, but also over voltages. Accordingly, it is mandatory to test High Voltage (HV) apparatus during its development stage. Protection of power system is an important aspect for the continued service of the electrical power system. Mostly the protection of electrical power depends on the performance of insulation systems under transient over voltage conditions arises due to lightning and switching applications. Transient over voltages along with the abrupt changes in the state of power systems, e.g. switching operations or faults are known as switching impulse voltages and that due to lightning are known as lightning impulse voltages. It has become generally identified that switching impulse voltages are usually the prevalent factor affecting the design of insulation in HV power systems for rated voltages of about 300 kV and above. Hence attention is required for these two types of over voltages. So in order to protect these equipments a prototype of the same can be used to test against lightning strikes.

A Marx Impulse generator is used to generate lightning impulse voltage. The magnitude and nature of test voltage varies with the rated voltage of particular equipment. It was originally described by E. Marx in 1924 and is primarily used because of its ability to repetitively provide high bursts of voltages especially when the available voltage sources cannot provide the desired voltage levels.

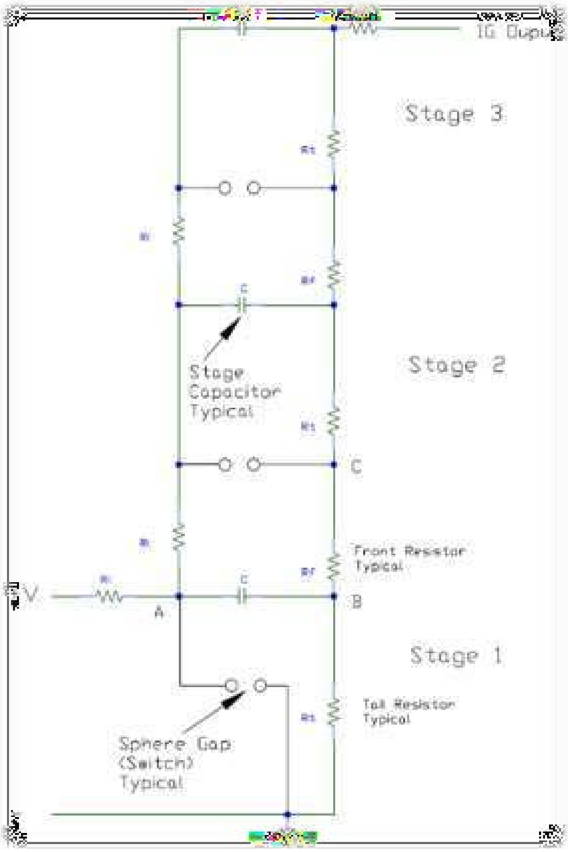

Figure 1.3. Stage Marx Genetrator

About Marx Generator Paper

Working Principle

This generator consists of multiple capacitors that are first charged in parallel through charging resistors by a high voltage, direct-current source and then connected in series and discharged through a test object by a concurrent spark over between the sphere gaps. The generated voltage from impulse generator must satisfy the standard values of voltage defined by the International Electro techno Commission in order to qualify as a standard impulse voltage that can be used for testing purposes .

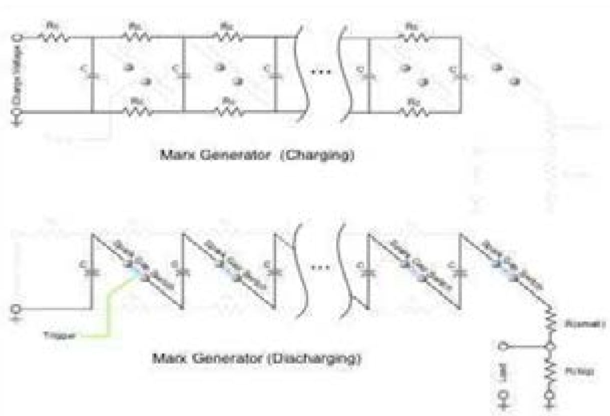

Figure 2.Marx Generator Principle

The standard methods of measurement of high-voltage and the basic methods for application to all types of apparatus for alternating voltages, direct voltages, switching impulse voltages and lightning impulse voltages are laid down in the important national and international standards. Although the wave shapes of impulse voltages occurring in the system may vary extensively.

Paper Objectives

The main objective of the paper is:

- To develop a High Voltage power supply for our paper Marx Multistage Impulse Generator.
- To develop a 6 stages Marx Generator prototype non working circuit to understand connections.
- To develop a practical 10 stages circuit model of Marx generator and to produce an impulse voltage

Table 2.Components used

Component	Rating or IC No	No. of Component
Micro- controller	Atmega 328	1
LCD	16 x 2 Character	1
IC	I2C	1
EHT	-	1
LED	Green	1
Optocoupler	PC817	1
Relay	12 V	1
Electrolyte Capacitors	10uF/50V	2
	2200 uF/25V	1
	1000 uF/25V	1
Ceramic Capacitor	104pF	6
	33pF	3
Crystal Oscillator	16 MHz	1
Diodes	1N4007	2
Zenor diode	-	4
Resistors	10 K Ω	8
	33 K Ω	1
	1 K Ω	3
	22 Ω	2
Variable Resistor	10 K Ω	3
Connector	4 Pin TBLOCK	1
	2 Pin TBLOCK	1
Copper PCB	10 cm x 6 cm	1
	15 cm x 3 cm	1
Transformer	12-0-12 V/	
500 mA	1	

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Designing of Marx Generator Power Supply

Primary energy supply is taken as a step down AC supply. Its means step down to suitable voltage and rectified to get consistent DC supply for charging of capacitors. Capacitors are charge storage tool. The charging of capacitor takes

- To provide two different kinds of high voltage DC supply one of EHT and other of Marx Generator prepare your paper before styling.

In this work, an attempt has been made to develop a compact, inexpensive, portable 10 stages Marx impulse generator circuit for demonstration of lightning impulses in academic institutions. This 10 stages Marx generator circuit, the same circuit was made practically. In addition, three different sorts of HV DC supply were made to test the practical circuit as well as to provide HV DC supply in laboratory. Finally, the simulated and experimental results were compared in terms of their magnitudes.

Main Components of Marx Generator

Place as they are parallel linked to the rectifier. When capacitor is having suitable charge saved in it, switches are used to attach all capacitor in series and discharge of capacitor take region and we get n times of rectifier voltage across the burden. Because of numerous sensible constraints, the output voltage is incredibly much less than n×V (in which n is a degree).

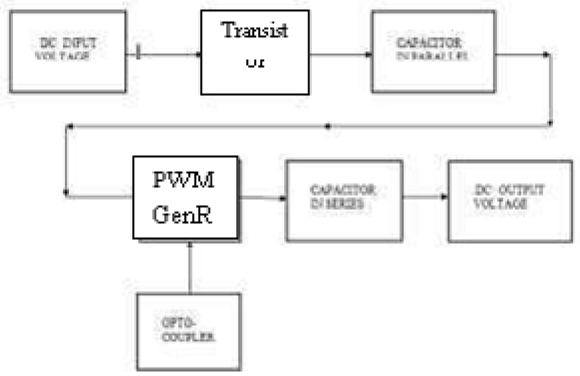

Figure 3.Marx Block Diagram

Designing of Marx Generator Circuit

The power supply is designed to provide large output voltages (dc), at low currents. The output can be regulated using the variable resistor on the outside of the box. Here are the important specifications.

Output voltage range: 1000 – 20000 V dc Maximum output

current: 20 mA

Input voltage: 210 - 250 V ac Input current: 0.5-1 amperes.

Average power of device: 40 – 60 watts

To power up the power supply, connect it to the ac-mains. Make sure that before powering up, the variable resistor knob is tuned to its lowest value, this must be ensured in order to minimize the risk of injury, as high voltages can be very dangerous. To use the power supply to get high voltages, connect probes to the positive and negative sockets provided on the auxiliary extension box. The potential difference will exist between these two probes. They can be connected in necessary places in various apparatuses used in high voltage experiments. There are many types of power supply. Most are designed to convert high voltage AC mains electricity to a suitable low voltage supply for electronic circuits and other devices. A power supply can by broken down into a series of blocks, each of which performs a particular function.

For example a 5V regulated supply:

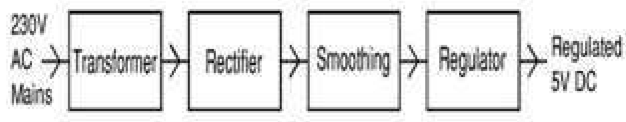

Figure 4 .Power Supply Block Diagram

Each of the blocks is described in more detail below:

Transformer - steps down high voltage AC mains to low voltage AC.

Rectifier - converts AC to DC, but the DC output is varying.

Smoothing - smoothes the DC from varying greatly to a small ripple.

Regulator - eliminates ripple by setting DC output to a fixed voltage.

Block Diagram

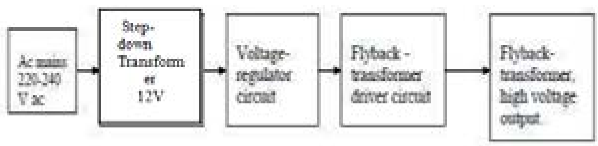

Figure 5.Flyback Connection

Step-down Transformer: This is basically a transformer that connects to the ac – main, steps the voltage down, and gives an output voltage of approximately 12 V. The core is made up of f-type plates. The primary contains about 1000 turns of insulated copper wire, with a thickness of about 30 swg. The secondary contains about 200 turns of copper wire, with a thickness of 28 swg. The secondary wire is thicker because more current will flow through the secondary than at the primary, as this is a step-down transformer.

Voltage regulator circuit: This is a simple circuit that as the main source of power for the flyback transformer and its driver. The circuit contains 3 outputs, one 5 V, one 12 V, and a regulated output, between 1-30 V dc. The output voltage of the regulated output can be changed from the

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variable resistor, and this is the main voltage that is given to the input of the flyback transformer, and hence it controls the output voltage.

Flyback-transformer driver circuit: This is a circuit that basically drives the flyback transformer. The main function of this circuit is to simulate a pulsed (square-wave), high frequency input for the flyback transformer, which then allows it to work. The square wave generated typically has a frequency between 25-100 kHz, in our case it was about 26 kHz, but the exact value can vary from one flyback transformer to another.

The circuit contains a transistor, which is put in the astable mode, this generates a square wave. The output of the transistor is fed into the input of a hex-inverter buffer. The output of this buffer acts as an open-collector, a sink for the 12 Vdc from the regulated circuit. Periodic transitions of the output of the buffer from open, to a short sink, allow it to switch the transistor on and off. The transistor being switched on and off is an n-channel MOSfet, in our case it is an IRF-540.

We chose this particular transistor because of its low drain-source resistance, so it heats up less.

The transistor is connected in a heavy-side driver configuration, in which the primary of the flyback transformer is placed between the drain and the regulated input from the voltage regulator circuit.

Flyback-transformer: A flyback transformer is a very interesting transformer.

Normal transformers, simply transformer energy from their inputs to their outputs. Flyback transformers, however, not only transfer energy to their secondary, but they also store energy for a considerable amount of time. In fact, flyback transformers act as pure inductors during half a cycle, and then they act as a pure transformer in the other half. This behavior is made possible by an air gap in the ferrite core. This air gap increases the reluctance of the core, which thereby increases its ability to store magnetic energy.

Flyback transformers are high frequency transformers, and their low output power and small size make them very useful in generating high output voltages, at relatively low currents. Their main applications are in televisions, monitors, and high voltage power supplies, like this one. The maximum attainable output voltage varies from transformer to transformer, but it is possible to get voltages as high as 50 KV, although the one we used generates 20 KV maximum.

The basic working of the transformer is as follows:

- During the time in which a current flows through the primary coil, no current flows through the secondary, due to a diode on the secondary, the energy is stored.
- When the input current in the primary is switched off, an emf is induced in the secondary, and this time the diode conducts, as its polarities are different. This induces a voltage, which is then rectified, and smoothed with a capacitor, giving us a dc output. The rectifier and smoothing circuit is built into the transformer, so we don't have to worry about it.

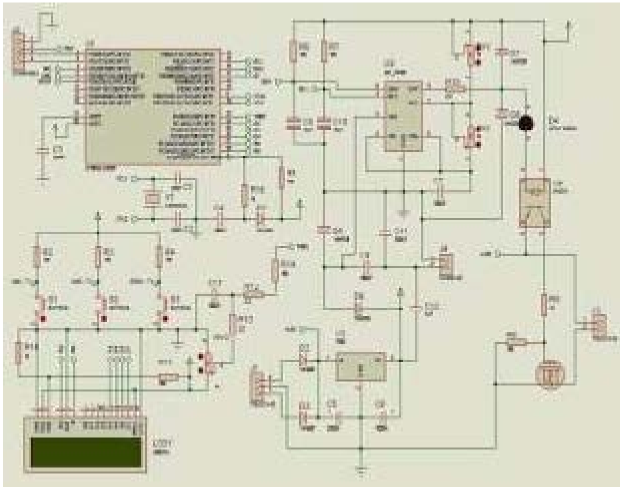

Figure 6.PCB Design for Power Supply

Performance Analysis

An experimental 10-stage Marx generator circuits built. This hardware part is divided into two main parts which are stages of Marx design and high-voltage DC supply to fire up these 10 stages.

The value of the charging resistor mainly depends on the type of power supply used. In this hardware circuit, 10 pieces of 1 M ohm, 2 watt, 500 V carbon film resistors are used and fastened. Two metal glazed resistors with value of 4.7M, 1 watt, 3.5 kV are used as a ballasting resistor to prevent a continuous arc to form across the first gap. This approach prevents the further firing of the Marx generator. Charging capacitors should ideally be ceramic as these are best suited to the fast pulses in a Marx generator.

A total of 10 pieces of 1 nF, 10 kV ceramic capacitors are used in this circuit so they become charged to the input voltage. The spark gaps are formed from thick tinnedcopper wire. Gaps should be curved. The sharp ends of the wire are bent away to avoid corona loss and premature breakdown.

Here, a resistive voltage divider is used to increase the level of the voltage to a measurable value and contains two resistors, a high-voltage resistor value of 100 k ohm (R1) and a lower leg value of 1 k ohm (R2).

The lightning voltage of a 10-stage Marx generator circuit with different distance of the output gap as well as in different tests (light and dark). All the gaps are broken down mostly at the same time. Basically, high-voltage DC source (fly-back transformer drive) is fed by 12 V voltage,

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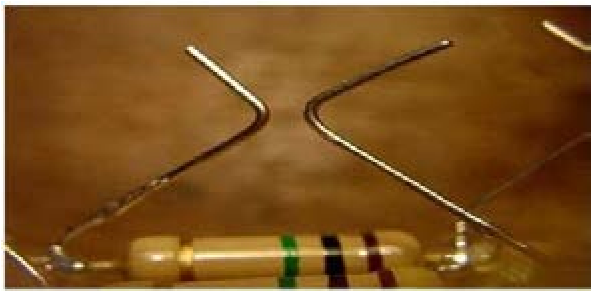

Figure 7.Single Spark Gap

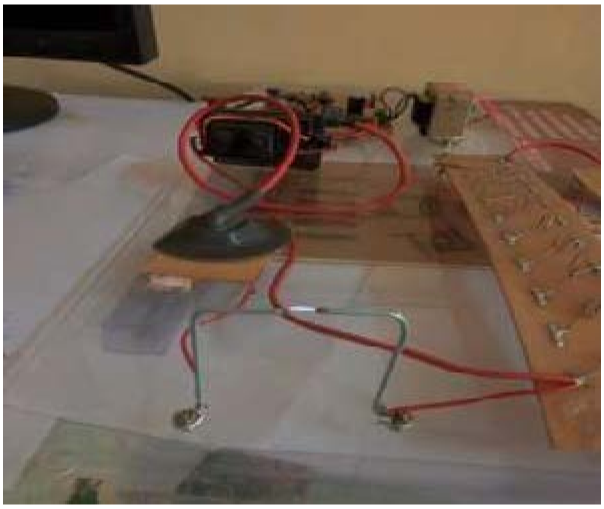

Figure 8.EHT Connection and Its Output

and the maximum output of the circuit is approximately 2 kV (DC). As a consequence, each stage is charged by 2 kV. Thus, the output lightning voltage should be 20 kV. Hence, 20 kV is generated by the Marx generator circuit.

Each sphere gap is adjusted to be curved with distance of 1- 2 mm, as shown in Figure-5.3. Figure-5.4 shows that all gaps are broken down almost at the same time to generate lightning voltage. In addition, the resistive voltage divider was connected to an oscilloscope to compute the magnitude of lightning voltage.

Figure 9.MARX CONNECTION

In practice, all the capacitors are not charged to the same value because of the turnout of series resistance in the Marx circuit. In theory, any desired output voltage could be obtained by increasing the number of stages. However, in practice, the effect of series resistance between the supply and distant capacitor limits the obtainable voltage. High-voltage DC source in simulation circuit was a constant source that gives an exact value to obtain accurate outcomes. However, in the experimental circuit, the high- voltage DC source was the designed single-transistor fly- back transformer drive that gives an output of 2.5 kV with tolerance of ±10%.

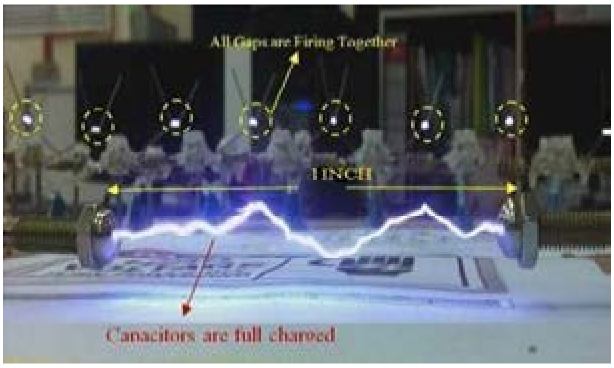

Figure 10.Output Of Marx Generator

Conclusion

In this paper, the applicability of an inexpensive and compact 10-stage Marx generator circuit for demonstrating lightning impulse voltage waveforms and testing low-rating power system equipment has been debated. This inexpensive compact Marx generator circuit has been made by our paper group. The experimental circuit was fired up by high-voltage DC generated by the singlet transistor fly- back transformer drive circuit.

The waveforms are controlled by changing the stage front resistor and tail resistor. Front time is controlled by changing the stage front resistor, and tail time is controlled by changing the tail resistor. The tolerances that are allowed in the front and tail times are respectively ±30% and ±20%. The ratio of capacitance of charging and discharging capacitors is taken as 40.

This Marx generator circuit can make peak impulse voltage of 45 kV. Specified the discrepancy of high-rating DC voltage source and certain loses that have been conferred, about 40 kV voltage could be generated. The experimental results were compared with simulation results, which were extremely desired and were in close agreement to standard impulse generator 1.2/50µs wave shape.

In this work, the entire circuit is modelled, simulated and almost intended in two dissimilar parts one from source to rectifier contains of the first part and the impulse Marx circuit methods the second part. The effects of the circuit parameters on the impulse wave characteristics is also studied and it is found that as long as the proper parameter selection is made the circuit will produce the standard waveform from the Standard as well as Improved Marx Impulse voltage generator.

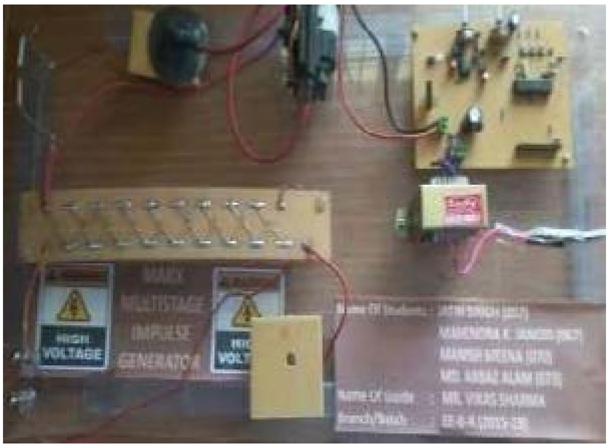

Figure 11.Marx Multistage Impulse Generator

Applications and Future Scope

- Generation of high-power microwave using virtual cathode oscillator devices.
- Lightning testing on cables and insulators at 1.2/50 us and 8/20 us.
- Material and dielectric testing.
- Breaking of raw diamonds in mineralogy. High voltage and magnetic pulser.
- High repetition rate high power CO2 lasers. Generating EMP on parallel plate transmission lines.
- Bridge wire exploding.
- Electron injection into nuclear reactors. Electron accelerators.
- Kilo amp linear accelerators. Current injection and generation.
- Demonstrating power by exploding objects. High power Nitrogen UV lasers.
- Energy beam experimentation.
- High power pulsed microwaves and RF. Nano particle generation.
- Radiation generator for high voltage steep pulser. Flash x-ray generation.
- Pulsed electron generation.
- Short duration luminous flash for ultra high speed photography.
- Firing boxes for pyrotechnic substance reliability testing.
- Exploding unattended munitions. Nuclear electroma gnetic pulse generator. Generation of plasma focusing.
- Generation of axial plasma for injection purposes. Remote de-programming of processors used in computers and other control circuitry.
- Educational demonstration of electrical pyrotechnics, etc.

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