Generation of Impulse Voltage using Marx circuit in MATLAB SIMULINK and Hardware Implementation

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Abstract— Various high voltage equipments are present in transmission substations. These kind of equipments are so costly and also important, their protection should be the higher priority. These equipment should not only tolerate the rated voltage which is the highest voltage of a system, but also over voltages. Accordingly, it is mandatory to test high voltage (HV) apparatus during its development stage. The insulation of such equipments must be tested under the given artificial lightning or switching overvoltages. This paper describes MATLAB simulation of Multi-stage impulse voltage generator circuit(Marx Circuit) to generate the impulse voltages of 1.2/50μs or 250/2500μs.

Key words: MATLAB SIMULINK, Impulse Voltage, Marx Circuit

I. INTRODUCTION

A. *Multistage Impulse Voltage Generator*

Multistage Impulse Voltage Generator is also known as Marx impulse voltage generator. Impulse generator is used to generate lightening impulse voltage. The principle on which Marx Generators work is; the capacitors are charging in parallel and discharging in series into the load circuit. The overvoltage of impulsive nature produced by this generator is used in testing of HV apparatus such as transformers, cables and insulators. Fig. 1 shows the schematic drawing of Marx impulse voltage generator.

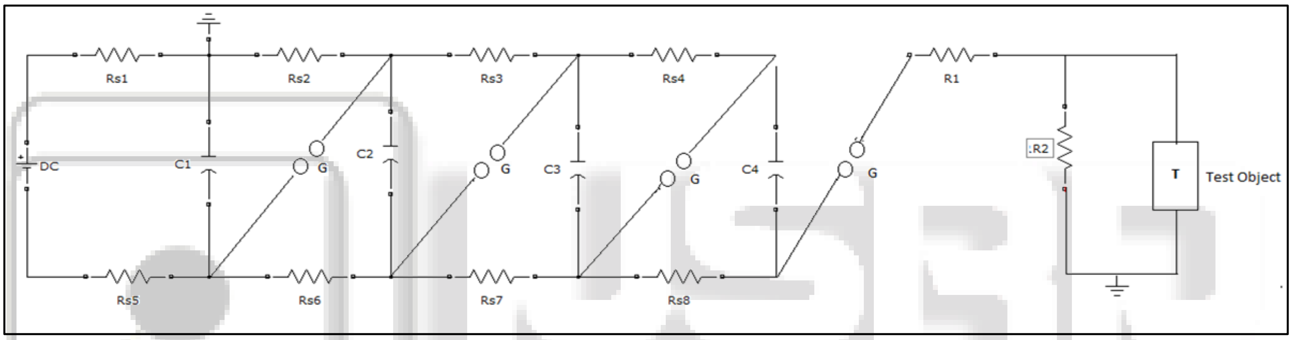

Fig. 1: Multistage Impulse Voltage Generator

The charging resistors (Rs) needs to be properly sized for both charging and discharging, generally in the order of 10 to 100 kΩ. Each resistor will design to have a maximum voltage between 50 to 100 kV. The generator capacitance *C* is chosen in such a manner that the product CRs will be about 10 s to 1 min.

The wave shaping circuit is connected externally to the capacitor unit. The wave shaping circuit comprises of wave front resistor (Rf or R1) and wave tail resistor (Rt or R2) Time taken for charging

$$T_1 = 3R_1 \times \frac{C_1 \times C_2}{C_1 + C_2}$$

Time taken for discharging

$$T_2 = 0.7 \times (C_1 + C_2) \times (R_1 + R_2)$$

As per the international standard, a full lightning impulse wave-shape is specified as having a wave front time (Tf) of 1.2μs ± 30% and a wave tail time (Tt) of 50μs ± 20%

II. MATLAB MODEL

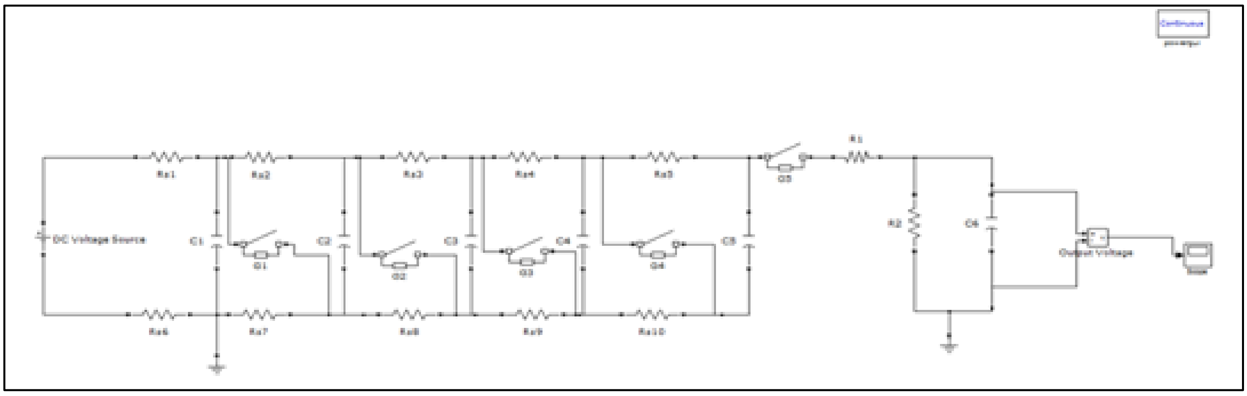

Fig. 2: Multistage Marx Generator MATLAB model.

Fig.2 shows the MATLAB model for multistage impulse generator. The spark gap in the circuit is replaced by circuit breaker in MATLAB model. The impulse voltage of standard time is obtained by triggering all five switches at the same instant. The wave front resistor allows the wave to reach peak magnitude in the desired time and wave tail resistor allows attaining 50% of peak magnitude at the end or tail of the wave shape.

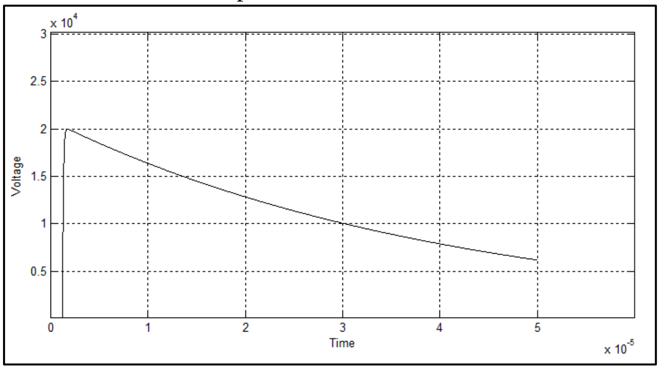

Fig. 3: Output waveform of multistage marx circuit.

Parameter	Value
Charging Resistor	270 kΩ
Generator Capacitors (C1 to C5)	0.7 µF
Load Capacitor (Test Sample)	3000 pF
Wave Front Resistor	136.19 Ω
Wave Tail Resistor	363.31 Ω

Table 1-Circuit parameters

ChargingVoltage (kV)	Expected Result	Simulated Result
4kV	20Kv	19.8kV

Table 2: Comparison of Simulated and Experimentally obtained Results

A. Second Stage Marx Circuit

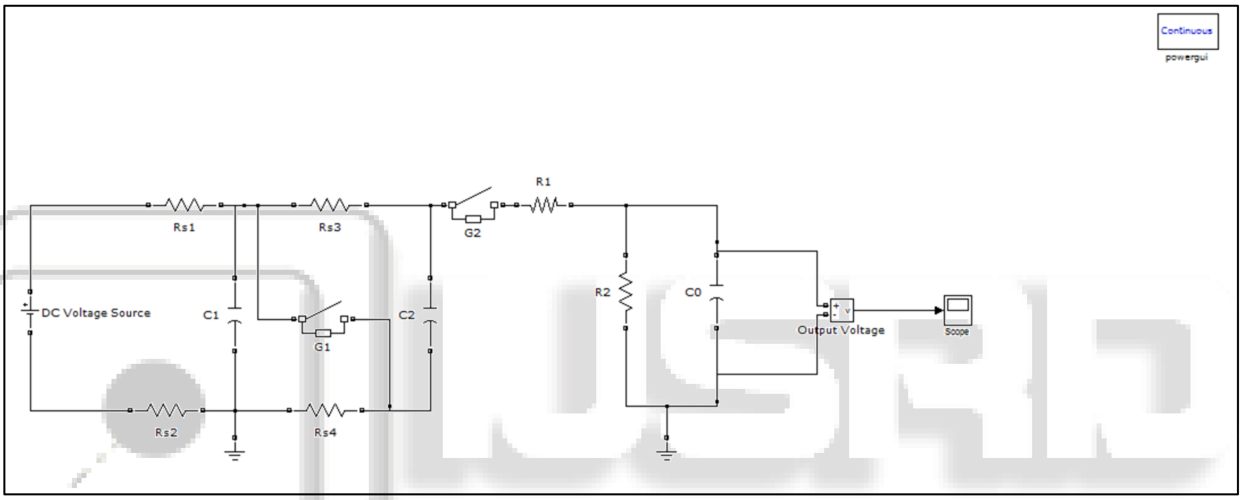

Fig. 4: Two stage Marx impulse voltage generator MATLAB model

Parameter	Value
Charging Resistor (Rs)	150kΩ
Generator Capacitors (C1 –C2)	20µf
Load Capacitor (Test Sample C0)	0.5µf
Wave Front Resistor (R1)	0.88Ω
Wave Tail Resistor (R2)	12.10

Table 3: Circuit parameter for simulation and harware

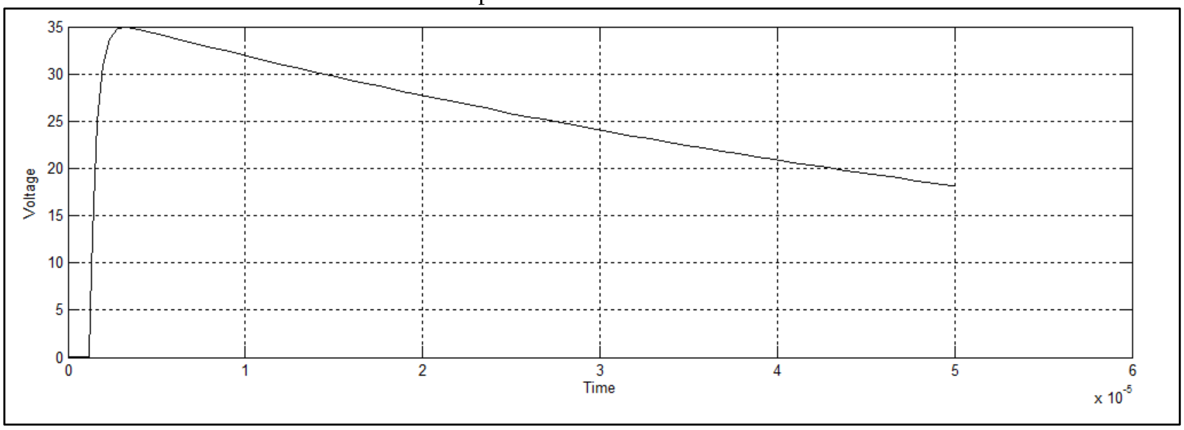

Fig 5: Waveform of 2nd Stage Marx circuit

ChargingVoltage (V)	Expected Result	Simulated Result
18V	36V	35.2V

Table 4: Comparison of Simulated and Experimentally obtained Results

B. Two stage standard Marx impulse voltage generator practical circuit model

Practical model of two stage standard Marx impulse voltage generator is shown in Figure 5.1. The transformer used for the circuit is a step down transformer of 230V/12V, 5mA. An AC supply of 230 V is provided to the circuit. The charging unit consists of circuit consists of charging capacitor C1 and C3 of value 20μF each. Charging circuit also consists of resistors R3 and R4 of values 150kΩ each. The discharging unit consists of capacitor C2 of 0.5μF and wave shaping resistors R1 of value 0.88 Ω and R2 of value 12.107Ω.

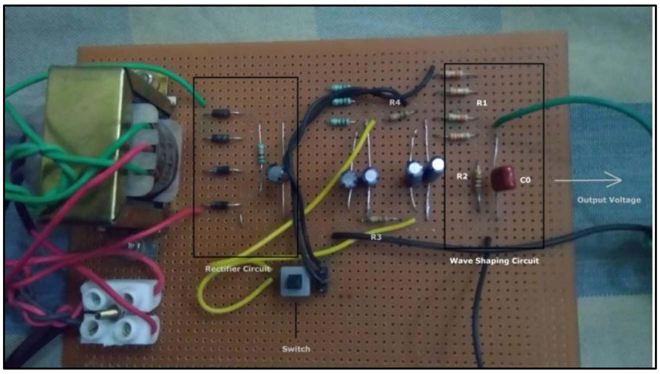

Fig 6: Two stage Marx Impulse voltage generator practical circuit model

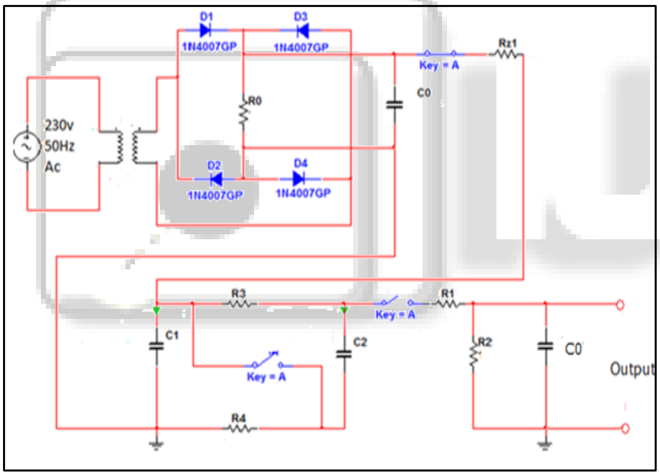

Fig 7: Connection diagram of two stage Standard Marx impulse voltage generator

Due to unavailability of resistors less than 1Ω the wave shaping resistor R1 was approximated to 1Ω. Five resistors of 5Ω each were connected in parallel to get a resultant of 1Ω. A resistor of 10Ω and 2.2Ω each were connected in series to get a approximate resultant of 12.107Ω. Two 1μF capacitors were connected to give the discharging resistor C2. In this circuit sphere gap is replaced by six pin switch which is having two NO contact and two NC contact. For the second stage two out of the six NO and NC contacts were used.

Two IN4007 Diodes were used for a full wave rectifier circuit. The output form the full wave rectifier circuit is 17.2 V DC. This DC voltage obtained is then applied to charging capacitors connected in parallel. The sphere gap which is replaced by a six pin switch has two NO (Normal Open) and two NC (Normal Closed) contacts. During charging time the output of the rectifier is connected to the charging capacitors and resistor circuit through a NC contact, which is then toggled to NO to manually trigger the circuit.

By pressing the switch the NO contacts changes to NC contacts and vice versa. So, the capacitors connected in parallel were made to operate in series by pressing the switch. At the same time the DC voltage supply is taken out with the help of the same switch through toggling operation. The output impulse is detected in the oscilloscope

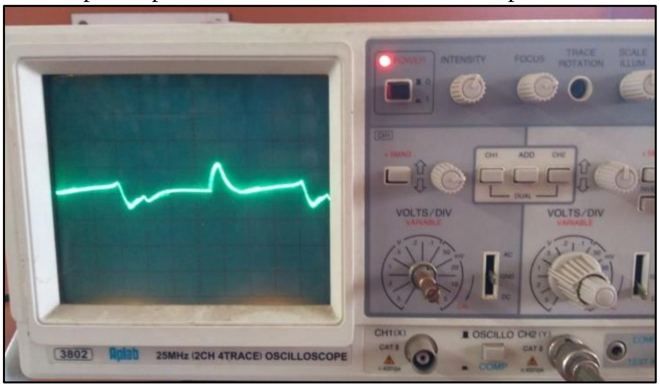

Fig. 8: Waveform recorded from CRO for IInd stage Marx impulse voltage generator

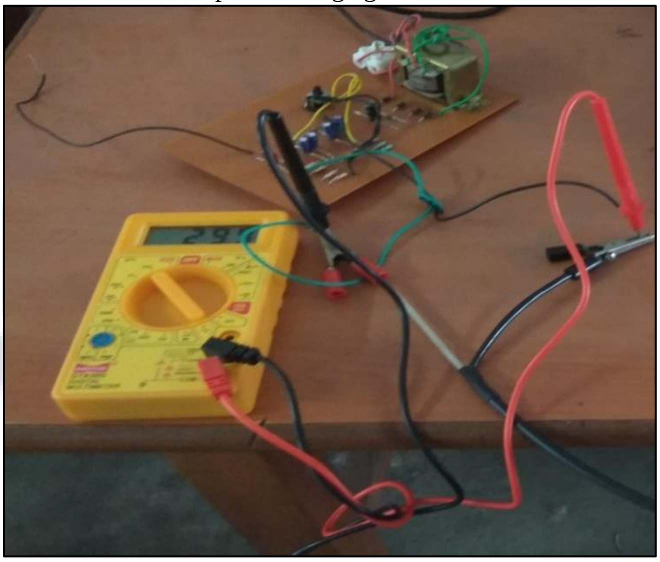

Fig. 9: Output Voltage of Hardware Circuit

ChargingVoltage (V)	Expected Result	Simulated Result	Observed Result
18V	36V	35.2V	29.5V

Table 5: Comparison of output of simulated and hardware model

III. CONCLUSION

A prototype of high impulse voltage generator is designed and is based on the simulation results performed in MATLAB software. The practical implementation of two stage Marx impulse voltage generator is made. The simulated result and the practical circuit result are close to the IEC standard wave shape for lightning impulse testing. In this work, the entire circuit is simulated and modelled based on the circuit parameters which were methodically calculated. The calculated parameters and their effect on characteristics of the impulse wave was studied and it was found that by the proper assumptions and the method followed in the work, the standard impulse wave can be generated.

This work can be further extended by making improvements in the circuit through modified Marx circuits which will not only make the design more compact and mobile but also the control over the wave shapes will increase as the resistances are more distributed throughout the circuit.

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