

A Novel Electrical Model To Achieve The IEC Standard Impulse Waveform (~60 KV), Measurable In A Normal Oscilloscope

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ABSTRACT: Standard high voltage impulse waveform has a very fast rising time and a comparatively slow decay time. This phenomenon can be achieved employing a standard impulse generator circuit. But, actual measurements of this waveform is very difficult due to its high voltage. In this article, the novel electrical model to achieve the IEC standard impulse voltage waveform (nearly 60 KV), that can be measured by a normal CRO maintaining the same result for different stages of the generator, is described.

Keywords: Impulse generator; Marx generator; IEC Standards; OrCAD Pspice; High voltage impulse.

1. Introduction

According to the International Electrotechnical Commission (IEC) standards, an impulse voltage can have different rising (T_1) and falling times (T_2), from which 1.2µs/50µs pulse is widely used for different purposes.[1] Generally, this kind of waveform is double exponential and expressed as:

$$V(t) = V_0 (e^{-at} - e^{-bt}) \quad \dots(1)$$

Where, $V(t)$ be the instantaneous voltage.

Production of such an impulse is not an easy task. Various methods can be used to develop such a system. Among them, a multistage impulse generator or **Marx Generator** is a convenient way to produce such a pulse. An impulse voltage or waveform is basically a spark or electrical discharge produced by some sort of source by which the mathematical equation given in equation (1) is obeyed. Each and every impulse waveform has a small rising time and a relatively long falling time. The maximum tolerance range in the rising time is ±30% and that is only ±20% for the falling time[1,7]. A waveform of standard impulse voltage is given below.

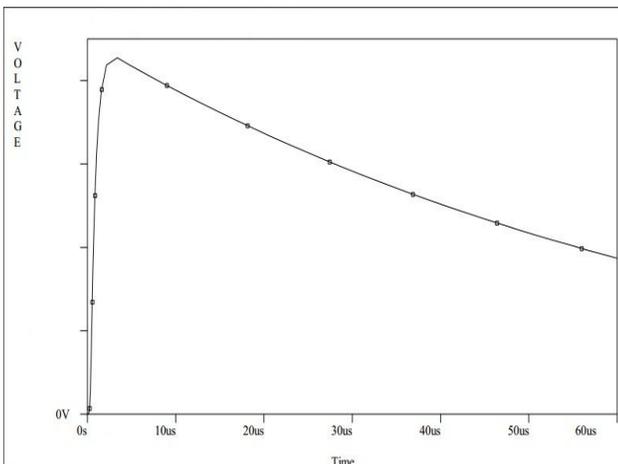


Fig 1: Standard impulse Waveform

Generally, an impulse waveform has a very high voltage, so it is a very difficult job to study such a high voltage waveform in a normal CRO. In this article, a novel process is described to measure a high voltage impulse through a normal CRO. The predicted simulation model is given here clearly. OrCAD is a proprietary software modified by “Cadence Design Systems” used in electrical simulations. The full form of “OrCAD” is “Oregon Computer Aided Design”. OrCAD includes various sub components like- Capture, Schematics, Pspice, Layout etc for different operations. This electrical simulation tool was first developed by “John Durbetaki, Ken and Keith Seymour” in 1985. OrCAD is very user friendly, cheap and a very good software by which impulse voltages can be generated and analyzed perfectly. In this article, OrCAD 9.2 software has been used to simulate the theoretical data.

2. Basics of an impulse generator circuit (Marx generator)

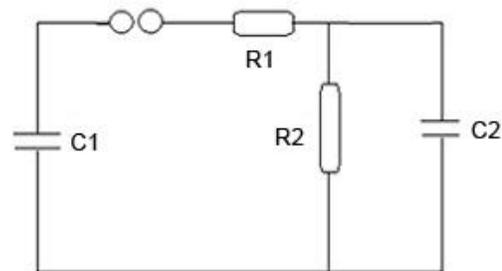


Fig 2: A standard Impulse Generator circuit

A charging capacitor (C_1), a spark gap, two wave shaping resistors (R_1, R_2) and a load capacitor (C_2) are consisted in a standard lightning simulator circuit. The whole circuit is charged by the charging capacitor. When the charging capacitor breaks down i.e., discharges, the spark gap is activated and a spark can be observed inside the gap. The wave shaping resistors are activated by this spark. The charging and discharging of the load capacitor is limited by these two wave shaping resistors [4]. During the charging of

the load capacitor, the current flows inside the capacitor. So, the rising time constant (T_1) will be dependent upon the equivalent capacitance of the circuit (viz. In series) and the charging resistor (R_1) only. Thus, the rising time constant of the impulse generator will be [1,4,7]:

$$T_1 = \frac{3R_1(C_1 \times C_2)}{C_1 + C_2} \dots\dots(2)$$

During falling time or discharging time (T_2) of the load, the current flows through the resistors R_1 and R_2 . So, the C_1 and C_2 are in parallel this time. So, the falling time constant of the generator will be [1,4,7]:

$$T_2 = 0.7 \times (C_1 + C_2) \times (R_1 + R_2) \dots\dots(3)$$

Like single stage lightning simulator, multi stage lightning simulator can also be made with the help of capacitors and resistors. A High Voltage DC source is used by the multistage lightning simulator or Marx Generator to drive the circuit. The voltage given to its input electrodes can be amplified by it. The capacitors in this circuit get charged in parallel and discharged in series [3,7]. This beautiful idea was first developed by **Erwin Otto Marx** and the circuit was named after him.

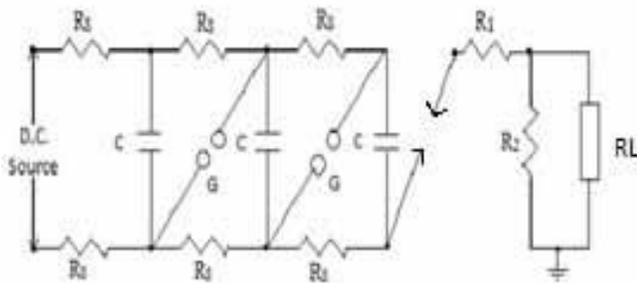


Fig 3: Multistage Impulse Generator (Marx Generator)

Marx generator is a light weight, flexible and cheaper way to produce standard impulse. The wave shaping circuit connected to it follows the same theory as mentioned earlier in the single stage pulse generator circuit.

3. Methodology

In our setup, we have chosen the following parameters (Table:1) for our Impulse generator circuit. The wave-shaping part of the circuit controls the rising (T_1) and the falling time (T_2). From the given equations (Eqn. no. (2) and (3)), the wave shaping parameters has been calculated and is given here in the Table:2 for different stages.

Sl. No.	Part Name	Value
1.	Input Voltage (V _i)	6KV
2.	Stage Capacitance (C)	2nF
3.	Stage Resistance (R _s)	1 Meg Ohm
4.	No. of Stages (N)	10

Table 1: List of parts of lightning generator circuit

Due to the high voltage output of the Impulse generator, the measurement of the impulse waveform is very difficult and risky to measure through a normal Oscilloscope. But in this model, a capacitive voltage divider along with a load resistance of 1 Kilo Ohm is used to minimize the output voltage which can be measured by any normal measuring gadget. The electrical simulation model in which different stages of the impulse generator has been used to prove the invariant character of the wave shaping circuit, will be shown in the following section of this article.

Details of the Wave shaping circuit (for two stages)		
5.	Charging resistor(R ₁)	15K Ohm
6.	Discharging resistor(R ₂)	59K Ohm
Details of the Wave shaping circuit (for five stages)		
7.	Charging resistor(R ₁)	15K Ohm
8.	Discharging resistor(R ₂)	160K Ohm
Details of the Wave shaping circuit (for ten stages)		
9.	Charging resistor(R ₁)	16K Ohm
10.	Discharging resistor(R ₂)	300K Ohm
Load parameters		
11.	Primary Load capacitor	47pF
12.	Secondary Load capacitor	4.7µF
13.	Load resistor (R _L)	1K Ohm

Table 2: Detailed Values of the calculated Wave Shaping Parameters

3.1 Two stage impulse generator simulation details

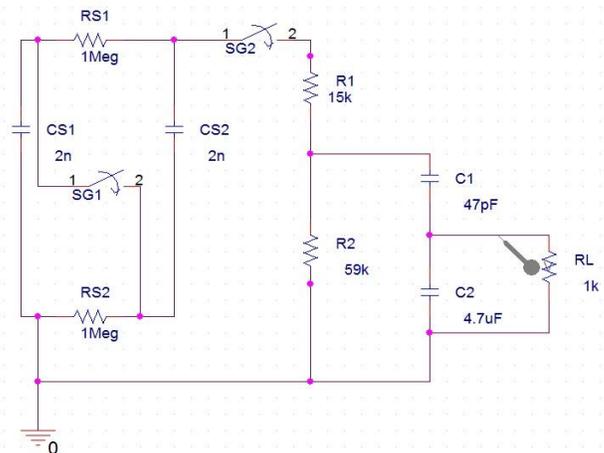


Fig 4: Two stage simulation circuit

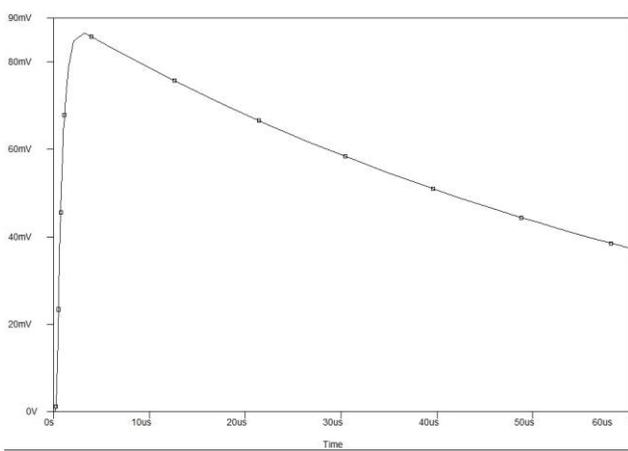


Fig 5: Simulation wave shape for two stages

3.2 Five stage impulse generator simulation details

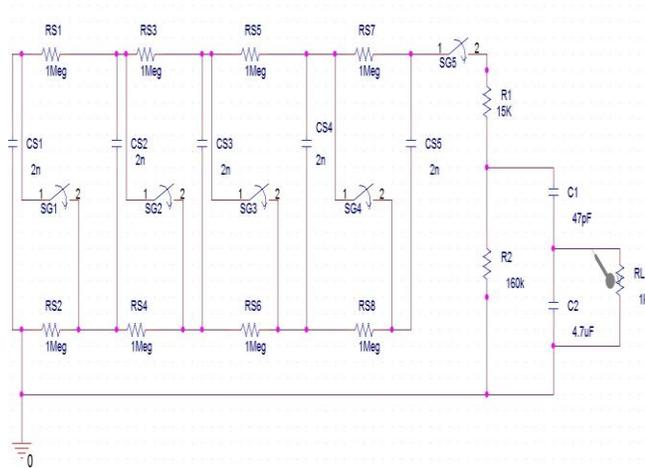


Fig 6: Five stage simulation circuit

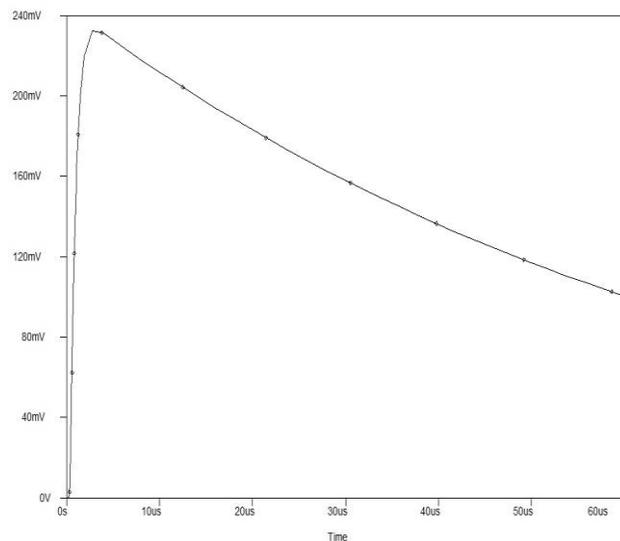


Fig 7: Simulation wave shape for five stages

3.3 Ten stage impulse generator simulation details

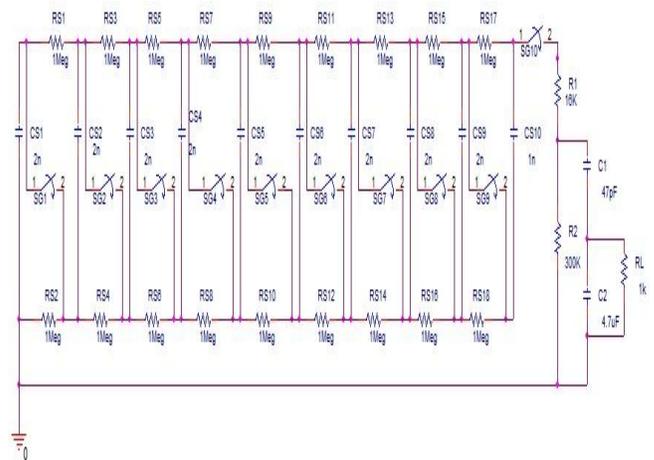


Fig 8: Ten stage simulation circuit

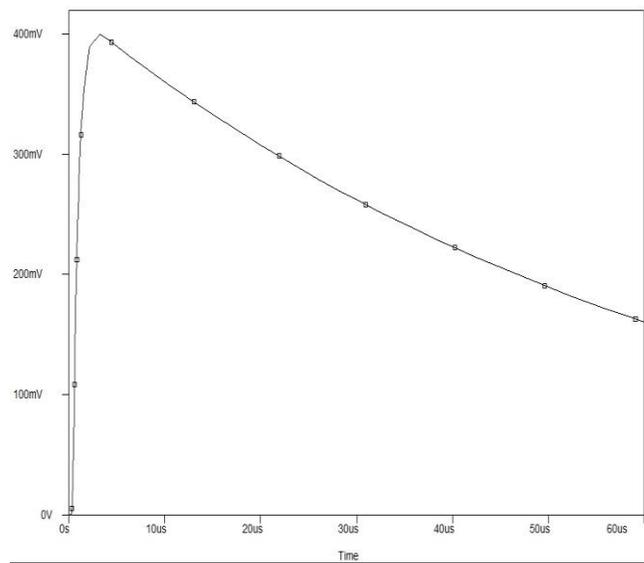


Fig 9: Simulation wave shape for ten stages Graph 3

4. Comparative study between different stages

A comparative study has been made between different simulation stages and the result has given in Table:3. It can be shown from Table:3 that, the error percentage is very low in case of the time period. Thus it can be said that, the impulse waveforms meets the IEC standard with a great accuracy for different stages.

State	Two stages		Five stages		Ten stages	
	T1	T2	T1	T2	T1	T2
Theoretical	1.2µs	50µs	1.2µs	50µs	1.2µs	50µs
Simulated	1.13µs	50.43µs	1.23µs	50.37µs	1.24µs	50.06µs
Error In Simulation	5.83%	0.86%	2.5%	0.74%	3.33%	0.12%

Table 3: A comparative analysis between each simulation stages

No. Of stages	Voltage With Wave Shape	Voltage without Wave shape (Calculated)
Two	86 mV	12KV
Five	236 mV	30KV
Ten	401 mV	60KV

Table 4: A comparative analysis between Voltages with and without Wave shaping circuit

5. Results and Conclusion

From the above study it is clear that it is possible to measure a high voltage impulse with a normal oscilloscope as the peak voltage lies in the range of 86 mV to 401mV (for different stages), with the help of a capacitive voltage divider along with 1K ohm load resistance. And it can also be said that with a wave shaping circuit, it is possible to shape the impulse wave form to reach the IEC standard with a very small percentage of error.

6. Acknowledgments

This project is entirely funded by Charuchandra College, Kolkata, India and is supported by **Dr. Muktinath Chatterjee** (Retd. Principal, Charuchandra College). The technical support is provided by **Mr. Arijit Basuroy**, M.D., Neo-teletronix, India. **Mr. Sayak Banerjee** and **Mr. Sandip Banerjee** was our constant support during this work.

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