International Journal of Advances in Engineering, 2015, 1(2), 45 - 50
ISSN: 2394-9260 (printed version); ISSN: 2394-9279 (online version)
url:http://www.venuspublications.com/ijae.html

RESEARCH ARTICLE

Simulation of characteristics of impulse voltage generator for testing of equipment using MATLAB Simulink

Devarajan.M and Premi.V
Kingston Engineering College, India
devavgt@gmail.com

Received 16 January 2015 / Accepted 11 February 2015

Abstract - This paper describes a method of modeling impulse voltage generator for testing insulator lab equipments. Impulse generator is an indispensible high voltage set. It simulates the voltage due to lightning and switching surges and used for testing of insulation of various electrical equipments like transformer, insulators etc. This paper describes a method of modeling impulse voltage generator using Simulink, an extension of MATLAB and it is specifically designed for simulating dynamic systems. It shows that Simulink program becomes very useful in studying the effect of parameter changes in the design to obtain the desired impulse voltages and wave shapes from an impulse generator.
Keywords –voltage generator, insulator, voltage generator, impulse voltage.

I. INTRODUCTION

A unidirectional voltage which rises rapidly to a maximum value and falls slowly to zero without appreciable oscillations are known as Impulse voltage. In it the maximum value is called the peak value of the impulse and the impulse voltage is specified by this value. In this wave shape small oscillations are tolerated, provided that their amplitude is less than 5% of the peak value of the impulse voltage [3].Transmission and distribution of electrical energy involves the application of high- voltage apparatus like power transformers, switchgear, overvoltage arrestors, insulators, power cables, transformers, etc. which are exposed to high transient voltages and currents due to internal and external overvoltages. Before commissioning, they are therefore tested for reliability with standard impulse voltages or impulse currents. Depending on the apparatus and the type of their proposed application, one differentiates between various types of waveforms of test voltages and test currents.

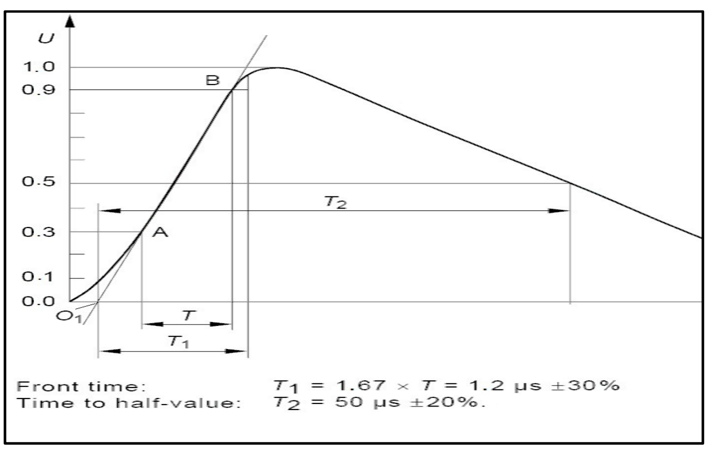

Figure.1 Full impulse voltage wave form with T1/T2

These waveforms are defined by several parameters with tolerances during generation and uncertainties during measurement [2]. For a lighting impulse voltage wave of 1.2/50 µs[[7].In the design or use of impulse voltage generators for research or testing, it is required to evaluate the time variation of output voltage, the nominal front and tail times and the voltage efficiency for given circuit parameters. Also, it needs to predict circuit parameters for producing a given wave shape, with a given source and loading conditions. The loading can be inductive or capacitive. The wave shapes to be produced may be standard impulse, steep fronted impulse, short tailed impulse or steep front short tailed impulse [1]. In this wave shape small oscillations are tolerated, provided that their amplitude is less than 5% of the peak value of the impulse voltage. In case of oscillations in the wave shape, a mean curve should be considered. If an impulse voltage develops without causing flash over or punctures, it is called a full impulse voltage. If flash over or puncture occurs thus causing a sudden collapse of the impulse voltage, it is called chopped impulse voltage [3]. During the application of impulse test specific waveforms of different magnitude are applied to each winding, voltage and neutral current traces are recorded [5]. Here for simulation of impulse testing MATLAB software is used.

II. IMPULSE VOLTAGE GENERATOR

a) General construction: An impulse generator essentially consists of a capacitor which is charged to the required voltage and discharged through a circuit. The circuit parameters can be adjusted to give an impulse voltage of the desired shape. Basic circuit of a single stage impulse generator is shown in Fig. 2.where the capacitor Cs is charged from a dc source until the spark gap G breaks down. The voltage is then impressed upon the object under test of capacitance Cb. The wave shaping resistors Rd and Re control the front and tail of the impulse voltage available across Cb respectively. Overall, the waveshape is determined by the values of the generator capacitance (Cs) and the load capacitance (Cb), and the wave control resistances Rd and Re. For a multistage generator, a group of capacitors are charged in parallel and discharged in series. The switch over of capacitors from a parallel connection to series connection occurs automatically when the intermediate spark gap breaks down after the capacitors are charged to the required potential Vo [4]. The voltage at the generator terminal is v(t) and is equal to n Vo where 'n' is the number of stages. Equation for the output voltage is given by,

$$v(t) = \frac{V_0}{C_b R_b (\alpha - \beta)} (e^{-\alpha t} - e^{-\beta t}) \quad (1)$$

Where, v(t) - instantaneous output voltage: V_0, DC charging voltage for the capacitor: α, β,

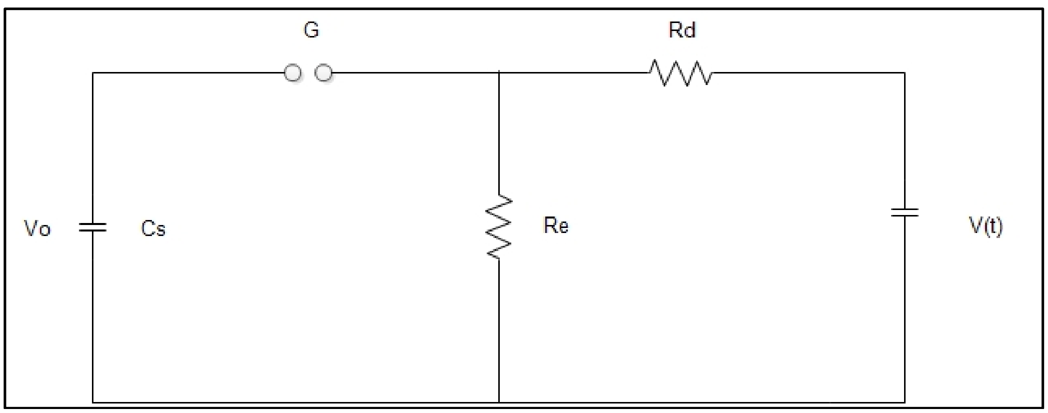

Figure.2 Basic circuit of single stage impulse generator

roots of the characteristics equation, which depend on the parameters of the generator. The exact waveshape, however, will be affected by the line inductance that comes from the physical dimensions of the circuit. Analysis using SIMULINK could become very useful in the proper selection of such components before even assembling them together.

b) Numerical analysis of impulse voltage generator:

The equivalent circuit of a high voltage multi-stage impulse voltage generator is shown in Fig. 2 and Fig. 3 gives the circuit of a 15 stage impulse voltage generator.

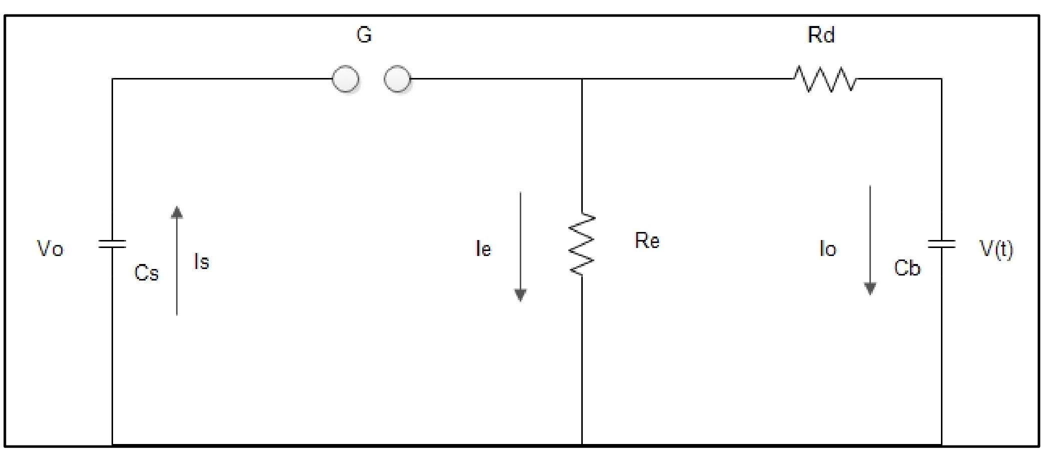

Fig.3. Equivalent circuit of multi-stage generator

The system equations may be put in the following form,

$$\frac{dV_0}{dt} = \frac{V_0}{C_s R_e} + \frac{i_0}{C_s} \tag{2}$$

$$\frac{dV_0}{dt} = \frac{i_0}{C_b} \tag{3}$$

$$Vo(t_0 + \delta t) = v(t_0) + \delta t\left(\frac{dV_0}{dt}\right) t = t_0 \tag{4}$$

Values of Rd, Re, Cs and C_b can be obtained by using the above equations [4].

c. *The IEC Surge standard:* The IEC 61000-4-5 standard defines a transient entry point and a set of installation conditions. The transient is defined in terms of a generator producing a given waveform and having specified open circuit voltage and source impedance. Two surge waveforms are specified: the 1.2 x 50µs open-circuit voltage waveform and the 8 x 20µs short-circuit current waveform.

III. CHARACTERISATION OF HIGH-VOLTAGE IMPULSES

a) Parameters of impulse voltage: For testing high-voltage apparatus, several wave shapes of the high voltage test impulses are standardised. In addition to switching and lightning impulse voltages with periodic waveform, oscillating switching and lightning impulse voltages, which are generated by transportable generators for onsite tests, are also standardised. Lightning impulse voltages are again sub-divided into full and chopped lightning impulse voltages, with the chopping occurring at widely variable times. Impulse voltages with an approximately linear rise are designated wedge shaped and those with a very steep front as steep-front impulse voltages [2].

Figure.4 Practical high voltage impulse generator

Dentitions of impulse parameters of high-voltage impulses are somewhat different from those commonly adopted in pulse techniques for low-voltage systems. That is considered essential in order to account for the special conditions during generation and measurement of high-voltage impulses. Fixing of these parameters is to be considered using theoretical investigation with mathematically prescribed functions, among others, calculation of the transfer characteristic of measuring systems with the help of the convolution integral. In fig.4.shows the practical high voltage impulse generator.

b)Lightning impulse voltage: The electrical strength of high-voltage apparatus against external over voltages that can appear in power supply system's due to lightning strokes is tested with lightning impulse voltages. One differentiates thereby between full and chopped lightning impulse voltages [2]. A standard full lightning impulse voltage rises to its peak value û in less than a few microseconds and falls, appreciably slower, ultimately back to zero. The rising part of the impulse voltage is referred to as the front, the maximum as the peak and the decreasing part as the tail. The waveform can be represented approximately by superposition of two exponential functions with differing time constants. Chopping of a lightning impulse voltage in the test field is done by a chopping gap, whereby one differentiates between chopping on the tail, at the peak and on the front . The standard chopped lightning impulse voltage has shown in fig.5. The voltage collapse on the tail shall take place appreciably faster than the voltage-rise on the front. Due to such rapid voltage collapse, the test object is subjected to an enormously high stress. Special requirements may be placed on the form of chopped impulse voltages for individual high-voltage apparatus.

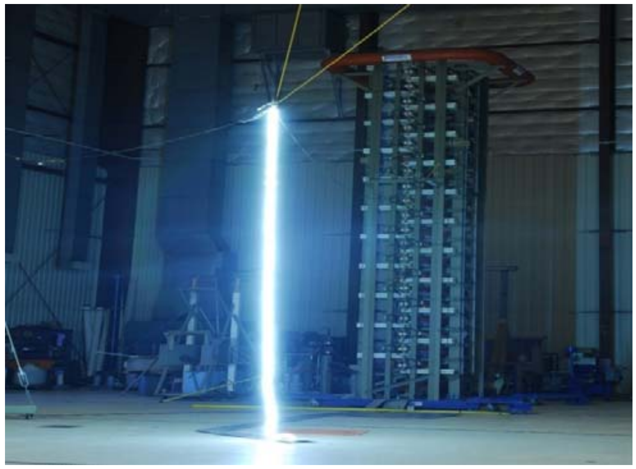

Figure.5 Practical impulse generation for testing

Steep-front impulse voltages are sometimes used in nuclear physics experiments. High impulse currents are needed not only for tests on equipment such lightning arresters and fuses but also for many other technical applications such as lasers, thermonuclear fusion, and plasma devices [8].

IV. SIMULATION RESULTS

Impulse voltage generator can be developed by MATLAB Simulink with standard blocks available in Simulink as shown in Fig. 6. The single-stage impulse voltage generator is simulated with the software. The stage sphere gaps were simulated by the use of switches, as shown. In the case of multistage system, each of the stage capacitors was given an initial charge voltage value, which is equal to 1/n of the total kV test voltage. The values of front and tail resistors, as well as the stage capacitors, are the same as used in the actual impulse generator. The impulse waveforms generated from MATLAB Simulink model with different front resistor shown in fig.6. In a large number of applications, the rise time of the impulse voltage is rather important and therefore, it becomes necessary to determine the effect of wave shaping control elements on the voltage waveform. Different desired outputs can be obtained simply by changing the values of capacitance and resistance. The dependence of the wave front on the front resistor and load capacitance is observed using Simulink. Impulse voltages created depends upon the switching speed and the capacitor stage values.

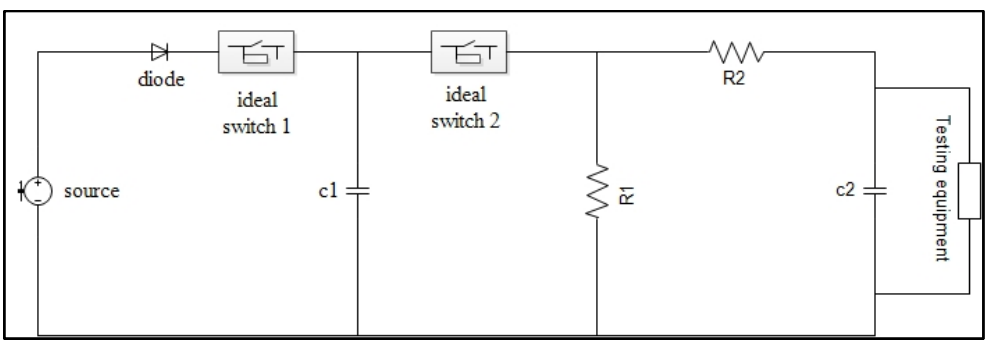

Figure.6 Block diagram of impulse generator

The output of the capacitor C1 as shown in figure 7. Front time and tail time of the impulse wave are, T1 is 1.2 µs and T2 is 50 µs. Hence, assuming the charging capacitor C1 to be 10µF and discharging capacitor C2 in µF, such that the ratio of C1/C2 will be within the given standard ratio. Substituting the value of charging capacitor C1, discharging capacitor C2 respectively, In fig.8 shows the output of the impulse generator with front and tail time. Changing the value for front resistor will affect the peak voltage. If the value of the front resistor is increased, the front voltage will decrease. In other words, the tail of the peak voltage is inversely proportional to the value of the front resistor.The shape of output waveform is also affected by load capacitor. Peak voltage of the output waveform will increase if the value of the load capacitor is decreased, and vice versa. For the final single stage impulse generation is done by using MATLAB software and the simulation waveforms as shown in the output.In practice all the capacitors are not charged to the same value due to the presence of series resistance in the circuit. In theory any desired output voltage can be obtained simply by increasing the number of stages. But in practice the effect of series resistance between the source and distant capacitor limits the voltage obtainable.

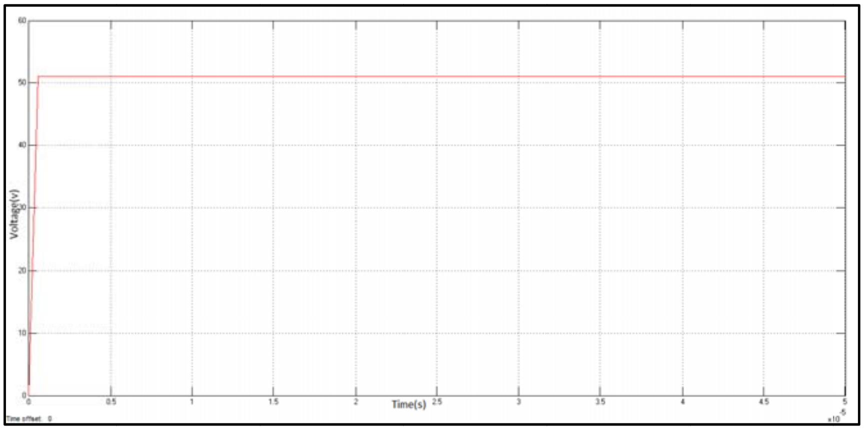

Figure.7 Output of the capacitor c1

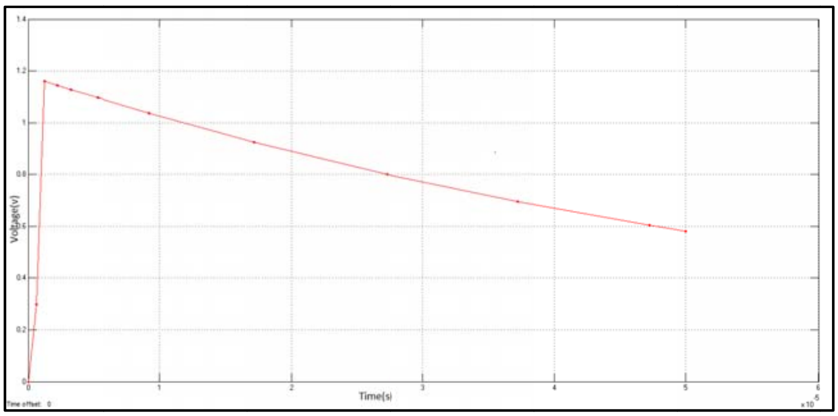

Figure.8 Output of the impulse generator

The error in rise time and fall time is because of some tolerance label in damping resistor and discharging resistor. It is also observed that a small change in the resistance value can cause significant change in rise time and fall time of the impulse voltage. The tolerances that is allowed in the front and tail times are respectively ± 30% and ±20 %. Rise time and tail time of impulse voltage wave obtained from simulated data are within tolerance limit.

CONCLUSION

The generation of high impulse voltage is implemented using MATLAB software. It is found that the overall simulated result and the observed impulse voltage result from the simulation results. The wave shapes are controlled by changing stage front resistor and tail resistor. Rise time is controlled by changing stage front resistor and tail time is controlled by changing tail resistor. The simulation output clearly shows the impulse generation for the equipment testing.

REFERENCES

[1] RamlethSheeba, MadhavanJayaraju, ThangalKunjuNediyazhikamShanavas, "Simulation of Impulse Voltage Generator and Impulse Testing of Insulator using MATLAB Simulink", World Journal of Modelling and Simulation,Vol. 8 – 2012.

[2] Schon.k, "High impulse voltage and current measurement techniques and measuring methods", springer-2013.

[3] Anitya Kumar Shukla, Dr. Ranjana Singh, "Analysis of Impulse Voltage Generator and Effect of Variation In Parameters by Simulation", International Journal of Electrical and Electronics Research, Vol. 2, Issue 3.

[4] M. Jayaraju , I. Daut, M. Adzman, "Impulse voltage generator modelling using MATLAB", World Journal of Modelling and Simulation Vol. 4 (2008) No. 1, pp. 57-63.

[5] BaudilioValecillos, and Jorge Ramirez, Senior Member, IEEE, "Evaluation of Lightning Impulse Test by Frequency Response Analysis", IEEE PES Transmission and Distribution Conference and Exposition Latin America, Venezuela.

[6] Muhammad SaufiKamarudin, ErwanSulaiman, MdZarafi Ahmad, ShamsulAizamZulkifli and AinulFaiza Othman, "Impulse Generator and Lightning Characteristics Simulation using OrcadPSpice Software", Proceedings of EnCon2008 2nd Engineering Conference on Sustainable Engineering Infrastructures Development & Management December 18 -19, 2008, Kuching, Sarawak, Malaysia.

[7] LavkeshPatidar *, HemantSawarkar, "Simulation of impulse voltage testing of power transformers using pspice",international journal of engineering sciences & research technology, patidar.

[8] Impulse generator, Wikipedia, the free encyclopedia.

[9] Sukanta Roy ,AnjanDebnath, “Procedural Perfection in Impulse Shape Generation for Indoor Type Impulse Test of Power Transformers, Global Journal of Researches in Engineering, Vol. 10, Issue 7.
[10] Z. StojkoviC*, M.S. Savid, Member, IEEE, J.M. Nahman, Senior Member, IEEE D. Salamon, Member, “sentivity analysis of experimentally determined grounding grid impulse characteristics” IEEE,IEEE Transactions on Power Delivery, Vol. 13, No. 4, October 1998.
[11] Preeti Nair , Prof. ArunPachori, “Design of impulse generators for different front and Tail Resistors in Impulse voltage testing of power transformers”, International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463 Vol. 2 Issue 12, December-2013.