Impulse Testing of Power Transformers For Effective Resistors Using Orcad Pspice

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ABSTRACT
High voltage equipments are often placed in open air and they are often exposed to lightning strike as well as surge voltage. Most of such high voltage power equipments are placed in the power transmission line. They are sustaining high surge voltage during the lightning phenomena. To protect all such power equipments and quality power supply the study of lightning characteristics is most important for every power engineers. The main objective of this paper is to simulate the standard impulse waveform of the impulse voltage generator circuit at front & tail resistive load and obtained results are showing graphically. The whole systems are studied in the Pspice software.

Keywords:- Impulse generator, power transformer, Pspice, spark gap.

1. INTRODUCTION
Most of the high voltage equipment such as power transformer, surge arrester, circuit breaker, isolator 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 equipments are often affected by lightning strokes and switching surge voltages which can cause insulation failure, incipient faults etc. So in order to protect these equipments a prototype of the same can be used to test against lightning strikes.

2. PRINCIPLE OF MARX GENERATOR
In Marx generator circuit a number of capacitor charge in parallel then discharging them in series. Originally described by E. Marx in 1924, Marx generators are probably the most common way of generating high voltage impulse for testing when the voltage level required is higher than available charging supply voltage.
The generator capacitance 'C' is to be first charged and the discharged into the wave-shaping circuits. A single capacitor may be used for voltages up to 200KV. Beyond this voltage, a single Capacitor and its charging unit may be too costly and the size becomes very large. The cost and size of the impulse generator increase at a rate of the square or cube of voltage rating. Hence, for producing very high voltages, a bank of capacitors are charged in parallel and then discharged in series.

A schematic diagram of MARX circuit and its modification are show in fig 1. Respectively usually the charging resistance 'Rs' is chosen to limit the charging current to about 50 to 100 mA, and the generator capacitance C is chosen such that the product (C×Rs) is about 10 sec to 1 min. The gap spacing is chosen such that the breakdown voltage of the gap 'G' is greater than the charging voltage 'V'. Thus, all the capacitances are charged to the voltage V in about 1 minute. When the impulse generator is to be discharged, the gaps G are made to spark over simultaneously by some external means. Thus, all the capacitors C get connected in series and discharge into the load capacitance or the test object. The discharge time constant CR1/n (for n stages) will be very very small (microseconds), compared to the charging time constant CRs which will be few seconds. Hence, no discharge takes place through the charging resistors Rs. In the Marx circuit is of Fig.1 the impulse wave shaping circuit is connected externally to the capacitor unit. The resistances R1 and R2 are incorporated inside the unit. R1 is divide into n parts equal to R1/n and put in series with the gap G. R2 is also divided into n parts and arranged across each capacitor unit after the gap G. This arrangement saves space, and also the cost is reduced. But, in case the wave shape is to be varied widely, the variation becomes difficult. The additional advantages gained by distributing R1 and R2 inside the unit are that the control resistors are smaller in size and the efficiency (Vo/nV) is high. Impulse generators are nominally rated by the total voltage (nominal), the number of stages, and the gross energy stored. The nominal output voltage is the number of stages multiplied by the charging voltage. The nominal energy stored is given by 1/2CV^2 where C = C/n (the discharge capacitance) and V is the nominal maximum voltage (n times charging voltage).

Figure 1:- Schematic diagram of Marx circuit arrangement for multistage Impulse generator

G - Spark gap
T - Test object
Rs - Charging resistors
R1, R2 - Wave shaping resistors
C - Capacitance of the generator
3. STANDARD IMPULSE WAVE SHAPE

An impulse voltage is a unidirectional voltage which, without appreciable oscillations, rises rapidly to a maximum value and falls more or less rapidly to zero Fig. 2. The maximum value is called the peak value of the impulse and the impulse voltage is specified by this value. 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 puncture, it is called a full impulse voltage; if flash over or puncture occur, thus causing a sudden collapse of the impulse voltage, it is called a chopped impulse voltage. A full impulse voltage is characterized by its peak value and its two time intervals, the wave front and wave tail time intervals defined below:

![Figure 2: Impulse Wave Form](image)

The wave front time of an impulse wave is the time taken by the wave to reach to its maximum value starting from zero value. Usually it is difficult to identify the start and peak points of the wave and, therefore, the wave front time is specified as 1.25 times \((t_2 - t_1)\), where \(t_2\) is the time for the wave to reach to its 90% of the peak value and \(t_1\) is the time to reach 10% of the peak value. Since \((t_2 - t_1)\) represents about 80% of the wave front time, it is multiplied by 1.25 to give total wave front time. The point where the line CO intersects the time axis is referred to be the nominal starting point of the wave.

4. SIMULATION OF IMPULSE VOLTAGE GENERATOR FOR DIFFERENT FRONT AND TAIL RESISTOR

In Impulse voltage testing of power transformer, the front time and tail time of the pulse are important therefore one must to observe the effect of the wave shaping control element on the voltage waveform. The dependence of the shape of the waveform on the resistors \(R_1\) (front resistor) and \(R_2\) (tail resistor) can be checked by changing the values of these resistors. Figs. 4 and 5 show s the output voltages of the impulse generator for different front and tail resistors.
Figure 3: Impulse generator test at different front and tail resistor.

**Graph view:** Output of impulse generator for different front resistor

Figure 4 (a): Pspice output wave with ($R_1=50\Omega$)

Figure 4 (b): Pspice output wave with ($R_1=80\Omega$)

Figure 4 (c): Pspice output wave with ($R_1=100\Omega$)
Table- I Simulation Result

<table>
<thead>
<tr>
<th>V(kv)</th>
<th>C(µf)</th>
<th>C_f(µf)</th>
<th>R_f(Ω)</th>
<th>R_2(Ω)</th>
<th>V_p(kv)</th>
<th>T_1(μs)</th>
<th>T_2(μs)</th>
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<tbody>
<tr>
<td>100</td>
<td>0.23</td>
<td>0.001</td>
<td>50</td>
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<tr>
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<td>1.0</td>
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<td>0.001</td>
<td>100</td>
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<td>258.9</td>
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<tr>
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<td>0.001</td>
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<td>900</td>
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Graph view: - Output of impulse generator for different tail resistor

Figure 4 (d):- Pspice output wave with (R_1=230Ω)

Figure 4 (e):- Pspice output wave with (R_1=250Ω)

Figure 5(a): -Pspice output wave with (R_2=600Ω)
Figure 5(b): -Pspice output wave with ($R_2=700\Omega$)

Figure 5(c):- Pspice output wave with ($R_2=900\Omega$)

Figure 5(d):- Pspice output wave with ($R_2=1100\Omega$)

Figure 5 (e):- Pspice output wave with ($R_2=1300\Omega$)
Table-II Simulation Result

<table>
<thead>
<tr>
<th>V(kv)</th>
<th>C(µf)</th>
<th>C(µf)</th>
<th>R1(Ω)</th>
<th>R2(Ω)</th>
<th>Vp(kv)</th>
<th>T1(µs)</th>
<th>T2(µs)</th>
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RESULT

The output voltage waveform of Marx generator circuit for effective value of front and tail resistors. In this paper gives the variation of front time, tail time & peak voltage. The front resistor (R₁) and tail resistor (R₂) show the effective value between front time (T₁) and tail time (T₂). If the value of front resistor increases from 50Ω to 250Ω and tail resistor fixed at 900Ω then it gives the changes value in front time (T₁), tail time(T₂) and peak voltage(Vp) as summaries Table-I. If the value of tail resistor increases from 600Ω to 1300Ω and front resistor fixed at 100Ω then it gives the changes value in front time (T₁), tail time(T₂) and peak voltage(Vp) as summaries Table-II. So better selection of standard impulse waveform for the value of front and tail resistor will be R₁=100Ω and R₂=900Ω.

CONCLUSION

This paper illustrates the Pspice model to simulate the impulse voltage testing of power transformer. Generate standard output impulse voltage waveform of 1.2/50 µs which leads to the simulation analysis on impulse voltage testing power transformer winding. Therefore, it is effective for educational purpose.

REFERENCE