International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 2 Issue 11, November-2013, pp: (171-178), Available online at: www.erpublications.com

Simulation and Impulse testing of Power Transformers at different values of inductive load by using PSpice software

Preeti Nair[1], Prof. Arun Pachori[2]
[1,2]Dept. of Electrical Engineering, Jabalpur Engineering College, Madhya Pradesh, India

Abstract: 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.The standard impulse waveform could be used to test the strength of electrical equipments against the lightning.Lightning characteristics and standard impulse wave form are related to each other.But the lack of relization about relation between them would make the solution to produce better protection against lightning surge becomes harder. The main object of this paper is to simulate the standard impulse waveform of the impulse voltage generator circuit at different values of inductive load and obtained results are showing graphically. The whole systems are studied in the PSpice software. The simulation circuit can be used to find out the desired front time, tail time, and peak voltage for different inductive loads.

Keywords: Impulse generator, impulse test, power transformer, PSpice software.

Introduction

Lightning is an electric discharge that occurs in the atmosphere between clouds or between clouds to ground. Lighting is a natural phenomenon, which generates simple unidirectional double-exponential impulse, which has a significant effect on power transmission system and equipment. Lightning surges induces high voltage of hundreds of kilovolts in the transmission towers and transmission lines. Lighting and switching surges due to transient over voltages cause steep building up of voltage on transmission lines and other electrical apparatus. The voltages are profoundly known as impulse voltage on transmission lines and other electrical apparatus .These voltages/currents are momentary and it is required to test the withstanding strength of the above said power equipments against such conditions. To simulates impulse voltages in the laboratory, we need a test setup for which a MARX generator can be used.

Principle of operation multistage MARX Type Impulse generator

A Marx generator is a clever way of charging a number of capacitor 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 C 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 become 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 Rsis chosen to limit the charging current to about 50 to 100 mA, and the generator capacitance C is chosen such that the product CRs is about 10 s 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 1minute. 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 CR5 which will be few seconds. Hence, no discharge takes place through the charging resistors Rs. In the Marx circuit is of Fig.1the impulse wave shaping circuit is connected externally to the capacitor unit .The resistances R1 and R2 are incorporated inside the unit.R1 is divided into n parts equal toR1/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 1/2 C1V2 where C1 = C/n (the discharge capacitance) and V is the nominal maximum voltage (n times charging voltage).

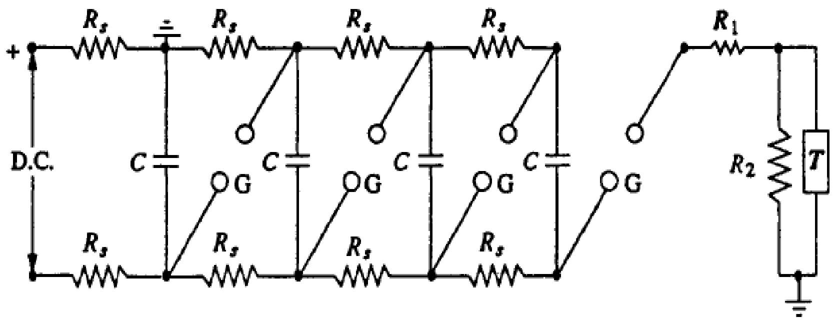


Fig1:-Schematic diagram of Marx circuit arrangement for multistage Impulse generator

C — Capacitance of the generator
Rs — charging resistors
G — Spark gap
R1, R2 — Wave shaping resistors
T — Test object

Standard Impulse Wave shapes

Transient overvoltage's due to lightning and switching surges cause steep build-up of voltage on transmission lines and other electrical apparatus. Experimental investigations showed that these waves have a rise time of 0.5 to. 10 µs and decay time to 50%of the peak value of the order of 30 to 200 µ sate wave shapes are arbitrary, but mostly unidirectional. It is shown that lightning overvoltage wave can be represented as double exponential waves defined by the equation

$$V = Vo\,[\exp(-\alpha t) - \exp(-\beta t)] \qquad (1)$$

.
Where α and β are constants of microsecond values.

The above equation represents a unidirectional wave which usually has a rapid rise to the peak value and slowly falls to zero value. The general wave shapes is given in Fig. 2. Impulse waves are specified by defining their rise of front time, fall or tail time to 50% peak value, and the value of the peak voltage. Thus 1.2/50 µs, 1000 kV wave represents an impulse voltage wave with a front time of 1.2 µs, fall time to 50%peak value of 50 µs, and a peak value of 1000 kV. When impulse wave shapes are recorded, the initial portion of the wave may not be clearly defined or sometimes will be missing. Moreover, due to disturbances it may contain superimposed oscillations in the rising portion. Hence, the front and tail times have to be too redefined.

Referring to the wave shape in Fig. 2, the peak value A is fixed and referred to as 100% value. The points corresponding to 10% and 90% of the peak values are located in the front portion (points C and D). The line joining these points is extended to cut the time axis at O1. O1is taken as the virtual origin. 1.25 times the interval
Between times t1 and t2 corresponding to points C and D (projections on the time axis) is defined as the front time, i.e. 1.25 (O1t2 – O1t1). The point E is located on the wave tail corresponding to 50% of the peak value, and its projection on the time axis is t4-O1t4 is defined as the fall or tail time. In case the point C is not clear or missing from the wave shape record, the point corresponding to 30% peak value F is taken and its projection t'1 is located on time axis. The wave front time in that case will be define 1.67 (01t3 – O1t1'), The tolerances that can be allowed in the front and tail times are respectively ± 30% and ± 20%. Indian standard specifications define 1.2/50 us wave to be the standard impulse. The tolerance allowed in the peak value is ± 3%.

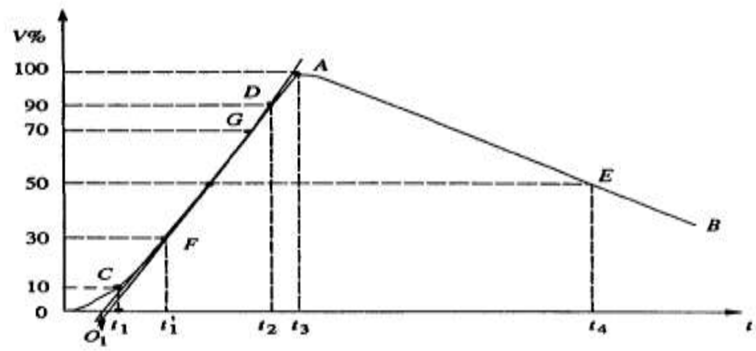


Fig: 2: Impulse Wave Form And Its Defination

Front time (T_1) = 1.2µs ± 30%   Time to half-Value (T_2) = 50µs ± 20%
Overshoot (µ) = <5%   Undershoot (u) = < 50%

"The time to front is defined as 1.56 times to time between 30% and 90% of the peak value in the rising portion of the wave. According to IS: 2071 (1973), standard impulse is defined as one with T_1 = 1.2µs, T_2 =50µs (called 1.2/50µs wave). The tolerances allowed are ±3% on the peak value, ±30% in the front time (T_1), and ±20% in the tail time (T_2)."

Simulation of test object

The Eight-stage impulse generator was simulated using PSpice software. The schematic of the simulated generator is shown in Fig 3. The stage sphere gaps were simulated by the use of switches, as shown. The output of the generator was also switched, and all nine switches were closed at the same time. Each of the eight stage capacitors was given an initial charge voltage value, which is equal to 1/8 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.

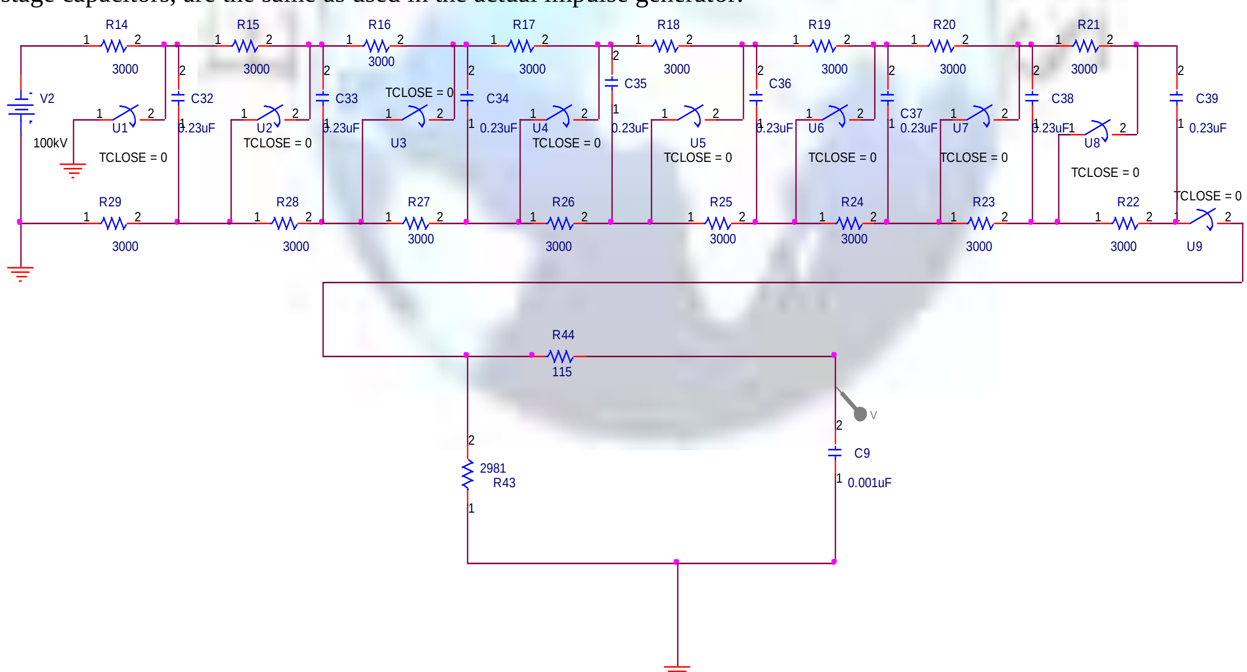


Fig. 3: Marx Generator circuit with PSpice Simulation

Here,

V = D.C . Charging Voltage (100Kv),
Cg, the geneator capacitance =0.23/8=0.02uF
Cl,the load capacitance=.001uF

Mathematical Solution

$$T1 = 3.0 \times R_1 \times \frac{C_g \times C_l}{C_g + C_l}$$

$$T1 = 3.0 \times 360 \times \frac{0.23 \times .001}{0.23 + .001}$$

$$T1 = 1.0\ \mu$$

$$T_2 = .7 \times (R_1 + R_2) \times (C_1 + C_2)$$

$$T2 = .7 \times (360 + 2981) \times (.023 + .001)$$

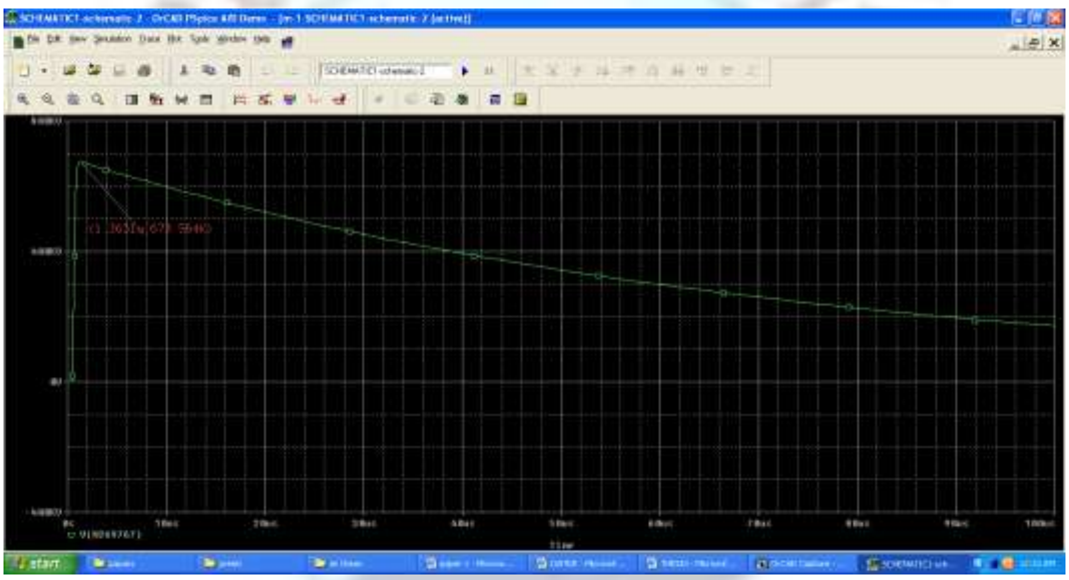
$$T2 = 49.1\ \mu s$$

But, experimentally the R1 = 115 Ohm we will be applied and obtained standard output wave form. The D.C. charging voltage for eight stage is:

$$V = 8 \times 100 = 800 kv$$

The maximum output voltage is=673.564 kv.

Graph View



T1 = 1.3 us T2=51.1 us

1. Impulse voltage test generator with inductive load:

In most of the cases power transformers cannot be assumed as a purely capacitive load for the LI (lightning impulse) testing. Usually the LI test voltage is applied to one winding terminal of the transformer to be tested, whereas all other terminals are connected with the earth. Hereby, not only the input capacitance of the transformer winding acts as the load for the impulse voltage test generator but also its impedance to all other short-circuited windings. The principal circuit (fig. 3) must be extended by the transformer inductance Lt that is connected in parallel to the test capacitance Ct (fig.4). Lt is Inductance of the load. Thereby the inductance Lt of the load becomes smaller with decreasing impedance voltage vimp%, with decreasing rated phase-to-phase voltage VP-P and with increasing power Ptot of the transformer winding to be tested. Therefore the lowest values of the inductance Lt have to be considered by testing the low-voltage side windings for power transformers. For a three- phase winding in a star connection the following equation can be applied.

$$L_t = \frac{v_{imp\%} * V_{P-P}^2}{100 * \omega * P_{tot}}$$

International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 2 Issue 11, November-2013, pp: (171-178), Available online at: www.erpublications.com

L_t	Inductance (stray inductance) of the winding to be tested
$V_{imp\%}$	Impedance voltage of the winding to be tested
V_{P-P}	Rated phase-to-phase voltage of the three-phase winding to be tested
P_{tot}	Rated total power of the three-phase winding to be tested
f	Rated frequency

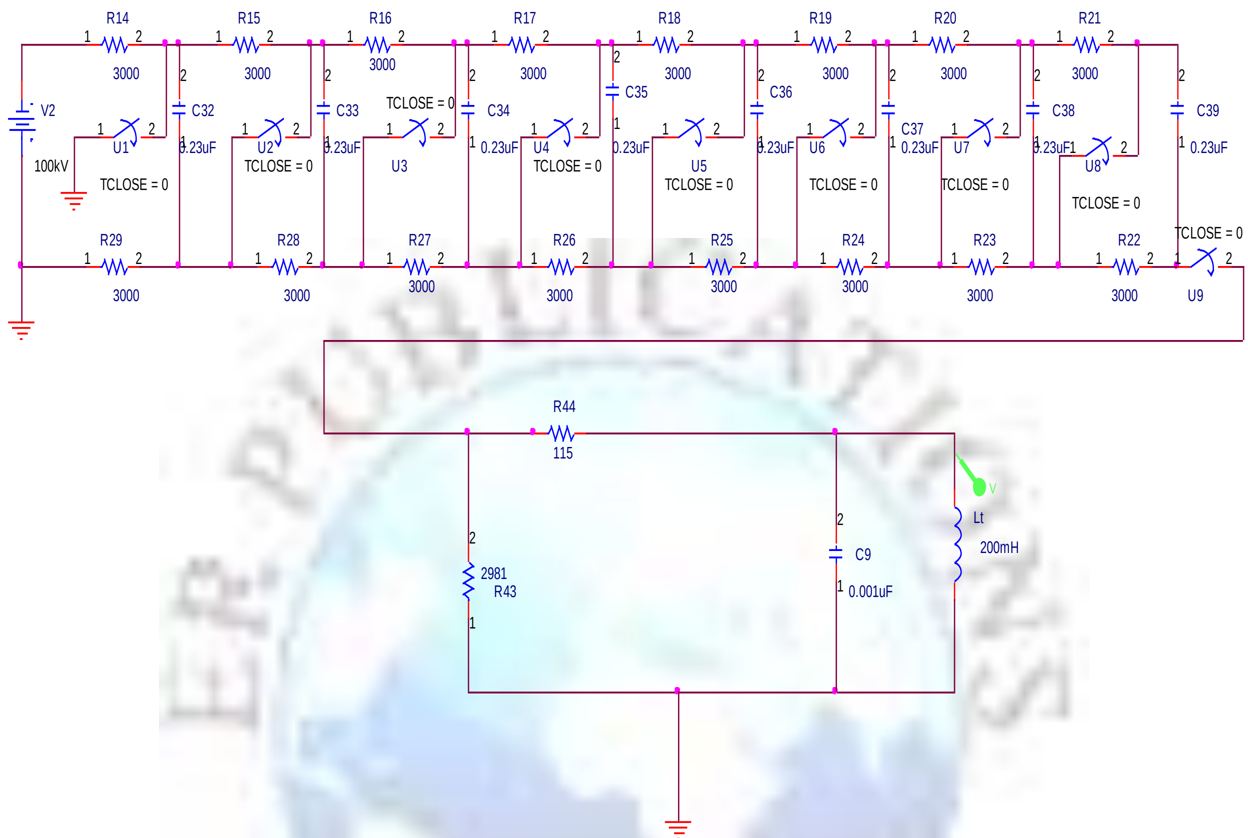


Fig 4: LI test at an induvtive/capacitive load

RESULT

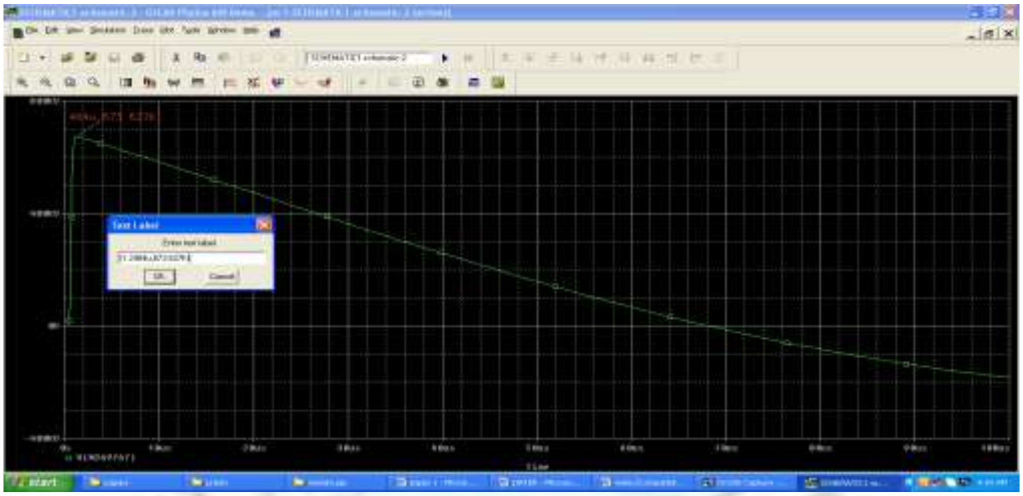
We can design the Impulse generator MARX circuit with Pspice simulation induced standard impulse wave form. inductance Lt of the load power transformer that is connected in parallel to the test capacitance Ct. We find out proper front time and tail time wae forms..Front time is obtained standard wave form but Tail time is not obtained standard wave form it is very difficult .inductive load Lt increase slightly tail time is also increase and we can obtained standard impulse wave form.

Table

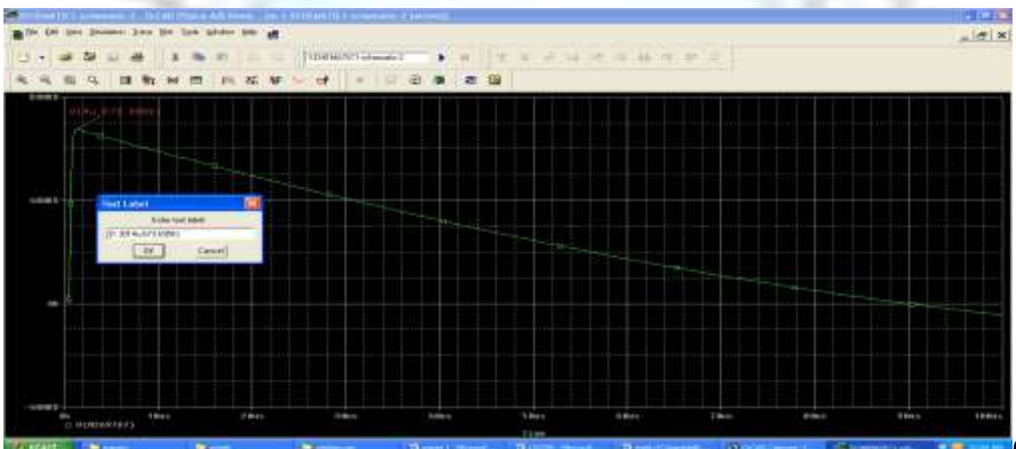
Curve	V(Kv)	Cg(µf)	R_1(ohm)	R_2(ohm)	Cl(µf)	L(mh)	Vp(Kv)	T_1(µs)	T_2(µs)
(1)	100	.02	115	2981	.001	100	673.627	1.2484	32.047
(2)	100	.02	115	2981	.001	200	673.695	1.3014	38.347
(3)	100	.02	115	2981	.001	300	673.616	1.320	41.260
(4)	100	.02	115	2981	.001	400	673.690	1.3119	43.488
(5)	100	.02	115	2981	.001	500	673.721	1.3113	44.354
(6)	100	.02	115	2981	.001	600	673.735	1.3128	45.354

EXPERIMENT RESULTS

Voltage shape depending on inductance factor Lt.

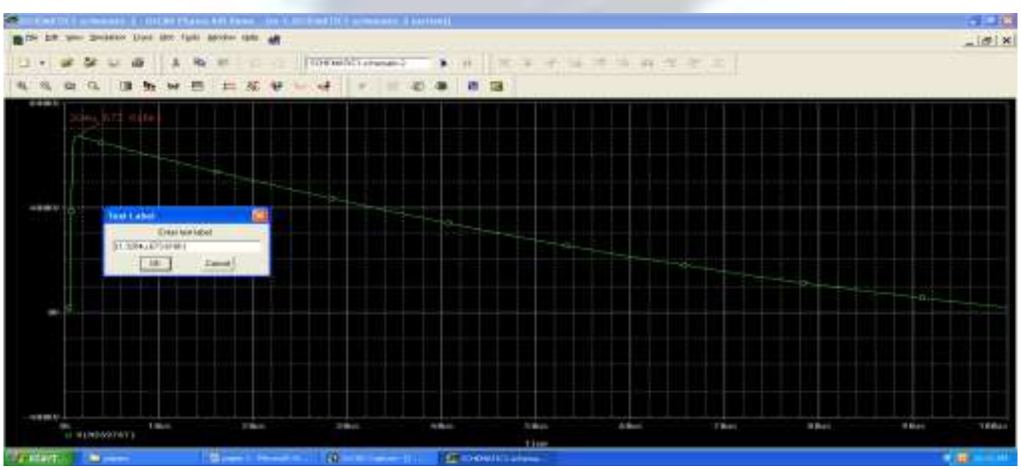


(a) Variation of inductance factor Lt at (100mh)



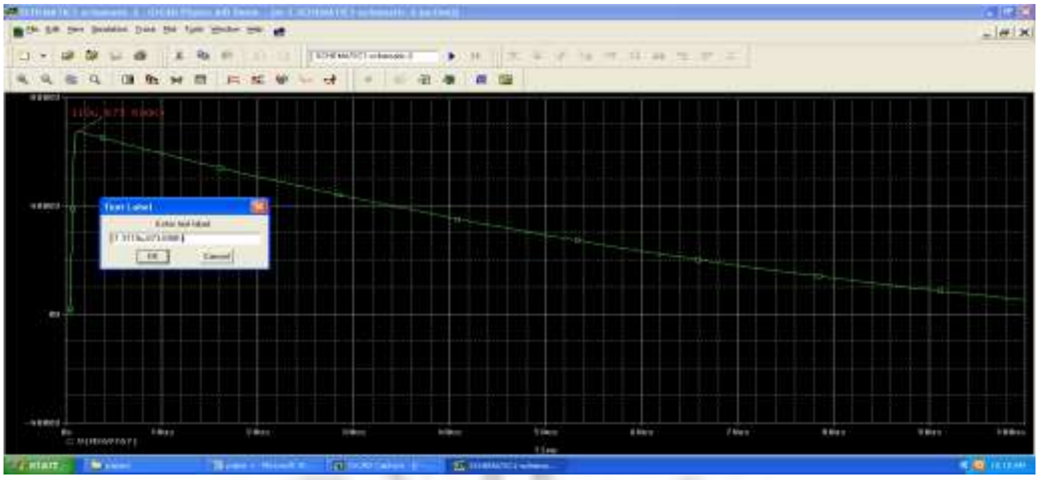
(c)

(b) Variation of inductance factor Lt at (200mh)

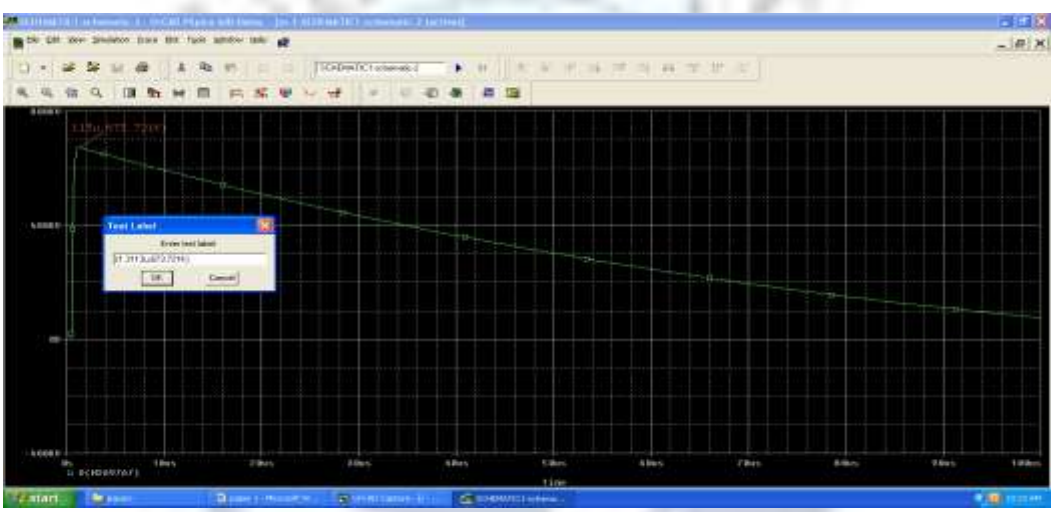


(d) Variation of inductance factor Lt at (300mh)

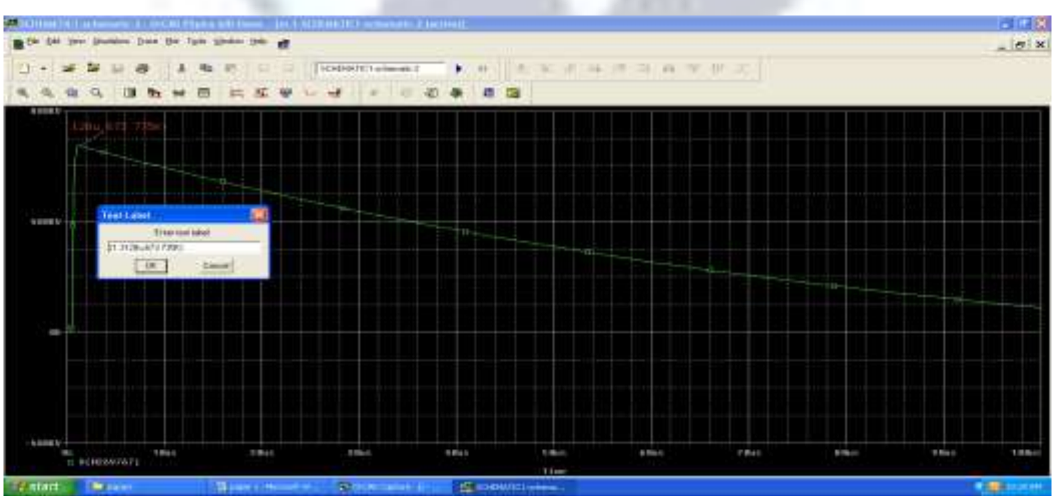
International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 2 Issue 11, November-2013, pp: (171-178), Available online at: www.erpublications.com



(e) Variation of inductance factor Lt at (400mh)



(f) Variation of inductance factor Lt at (500mh)



(g) Variation of inductance factor Lt at (600mh)

Conclusion

The testing of power transformers with LI test voltage according to the IEC standards presupposes special knowledge of the interaction between the impulse voltage test generator and the inductive load. For example, there exists a close connection between the main data of the transformer to be tested and the required impulse capacitance of the impulse voltage test generator. There are also requirements related to the damping characteristic of the test circuit to utilize an existing impulse voltage test generator optimally. Some basic aspects and circuitries were described in this paper.

References

[1]. "Impulse voltage test of power transformer" by W. Schrader HIGHVOLT Prüftechnik Dresden GmbH and W. Schufft Chemnitz University of Technology, Germany Workshop 2000, Alexandria, Virginia, 13 & 14 September 2000.

[2]. Muhammad saufi kamrudin , Erwan sulaiman ,Md Zarafi Ahmad ,shamsul Aizam Zulkifli and Ainul Faiza othamn. By "Impulse generator and Lightning characteristics Simulation using Orcad Pspice software". Proceedings of EnCon2008 2nd Engineering Conference on Sustainable Engineering Infrastructures Development & Management December 18 -19, 2008, Kuching, Sarawak, MalaysiaENCO2008-F-27.

[3]. "Prametric analysis on Impulse voltage generator and power transformer winding for virtual High Voltage Laboratory Environment" by Sachin Kumar, N K Kishore and B HemalathaI ndian Institute of Technology Kharagpur-721302, India on 16th National Power Systems Conference, 15th-17th December, 2010

[4]. "Using PSpice in Teaching Impulse Voltage Testing of Power Transformers to Senior Undergraduate Students" by Behrooz Vahidi, Senior Member, IEEE, and Jamal Beiza Ieee Transactions On Education, Vol. 48, No. 2, May 2000

[5]. D.J.Swaffield1*, P.L.Lewin1, N.L.Dao1 and J.K.Hallstrom2 "Lightning impulse wave-shapes: defining the true origin and it's impact on parameter evaluation"on 1University of Southampton, Southampton, Hampshire, SO17 1BJ, UK Helsinki University of Technology, 02015 TKK, Finland.

[6]. "High Voltage Engineering" fourth Edition by (Late) M S Naidu Department of High Voltage Engineering Indian Institute of Science Bangalore and V Kamaraju Department of Electrical EngineeringCollege of Engineering Jawaharlal Nehru Technological UniversityKakinada. McGraw-Hill

[7]. Introduction of PSpice Software from University of Pennsylvania Department of Electrical and Systems Engineering PSPICEA brief primer.