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Contribution in the Modeling of Trial System Under High Voltage Shocks by Numerical Simulation

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Abstract: This study treats the modeling a trial system under high voltage shocks. It's concerns the generator of shock wave above all with steep front which represents the main element of the installation of high voltage and the equipment corresponding. Then the elaboration of software of simulation on computer which represents the behavior of the whole installation in shocks of voltages.

Key words: HV impulse generator, simulation, modeling, HV shocks, software, installation

INTRODUCTION

The dielectric tests of skills medium and of high voltage of equipment call in two trial types:

- Try under high voltage perms.
- Try under shock wave.

Forms of voltages for tries under high voltage permanent is alternative and uninterrupted, while the most common forms of the waves of voltage applied for tries under shock wave are those corresponding in the shock of lightning (1.2 µs 50 µs•^{1}) and in the shock of switching (250 µs 2500 µs•^{1}). Nowadays tendency is to impose this trial type more and more often on the equipment low voltage and to apply shock waves to much more steep front. In this context, which lets envisage a bigger requirement as for precision both on amplitude and on form of the applied waves, it appears necessary to develop the possibilities of simulation of trial systems under high voltage of shock. In effect the shock wave produced in an installation of high voltage depends not only on the generator but of course on the object which is in try. It is therefore necessary to adapt these two groups by external components to acquire the form of desired wave. Amplitude and form of impulsion (rise time and width) depend on the load impedance, the matching resistance, the ground connection of the sheath of co-axial cable and the type of HV switch (Xu and Jayram, 1995; Seki *et al*., 1994). In the same order of idea, the only approachable greatness by the operator is in mediated her of a chain of measure which is likely not to reproduce the real sign truthfully. It is obvious that the tools of simulation developed as part of tries of high voltage will have to arrest the system in its entirety, chain of including measure.

Job introduced here is made up of two parties:

- Development of a program of simulation.
- Modeling of some elements of a trial system as part of preceding program.

PROGRAM OF SIMULATION

This program is envisaged to allow the counting of the answer free from a circuit imposed initial conditions. This simulation puts into play of course inductance, capacities and resistance but also lines with constants divided to take into account phenomena of spread. The evolution of greatness in time will be calculated by a method step by step (• t represent the step of counting). Feigned network is put in equation by a nodal analysis, where into final all elements are so transformed in constant resistance with sources of current on which the value will depend of voltage and current at a walking pace of preceding counting. It allows therefore to calculate the evolution of circuit easily step by step in time. After the transformation of elements, they will have a purely resistive circuit, the equation of every element have the same form:

$$i_{km}(t) = Y\left[v_k(t) - v_m(t)\right] + I_{km}(t - \Delta t) \qquad (1)$$

The simulation of this circuit plays made by the resolution the nodal equation of that ci according to:

$$I = Y \cdot V \qquad (2)$$

V : Matrix column of nodal tensions
I : Matrix column of the currents

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PRESENTATION OF THE PROGRAM OF SIMULATION

Simulation is made by two programs among which the one is an interactive program allowing to create and to change a file of data. To make easier the introduction of data concerning the generator of high voltage which is in general the most complex element of the trial system, an option in the program of entrance allows to represent this element simply (Mazetti and Ratti, 1972; Heilbronner, 1971; Aguet and Ianoz, 1990). A generator of high voltage being constituted by several serial put identical floors, it is enough to represent elements and to give the number of floors as well as the number of knot of connection of the generator in network (dipole generato being so linked between this knot and the knot number 0 which corresponds to the plan of mass). The second allow to get data and to calculate V. This program of simulation introduces a big suppleness of job at the level of the possibilities of entrance and exit. Nevertheless this tool of simulation does not resolve absolutely the problems which settle to the experimenter in high voltage. It is necessary to him to model systems in effect in try as part of possibilities given by this program.

MODELING OF THE EQUIPMENT

In this party we are going to develop an example of modeling of equipment of high voltage. A trial system in high voltage is made up in general a generator of shock, object in try, braid resistive, divisor bridge.

The role of the braid resistive being of course to assure link between the generator and the object to be tested, but also to regulate the time of rise of the wave of voltage applied to the object to be tested. To diminish the influence of clean reactance of the braid, they conceive it under the form introduced in Fig. 1.

In general, they consider the resistive braid as a component with constant located for typical applications under shock of lightning (1.2 μs 50 μs•[1]) produced by the generator. On the contrary when the wave produced by the trial system introduces a comparatively short time of rise (t_{rise}= 1 μs). It appears regard shoots on the forehead of wave (Fig. 2-5).

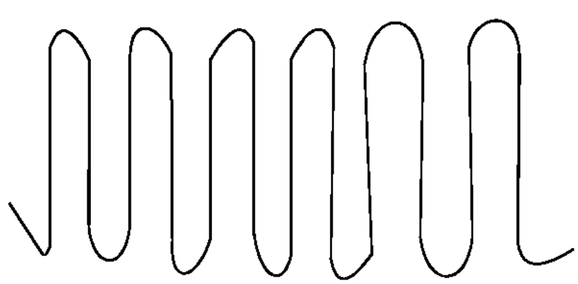

Fig. 1: Form of the braid resistive

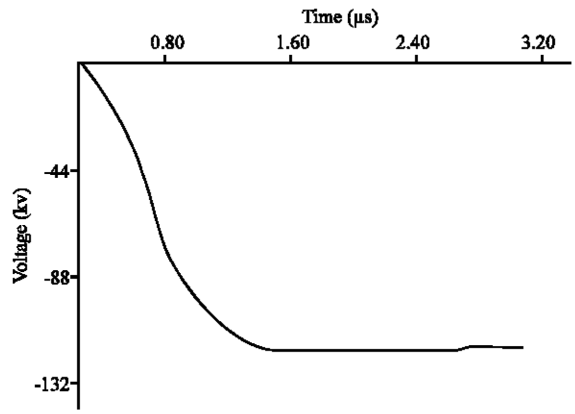

Fig. 2: Form of measured wave

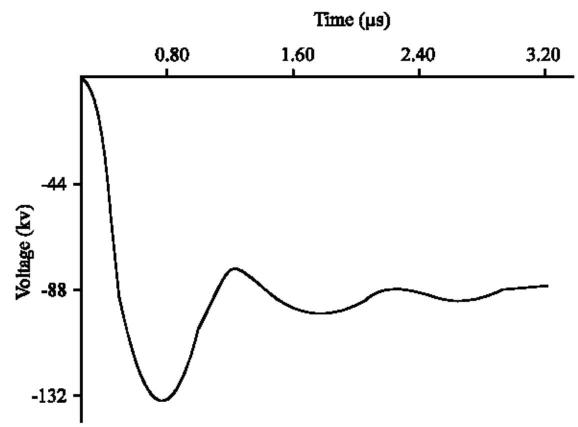

Fig. 3: Form wave measured with steep front

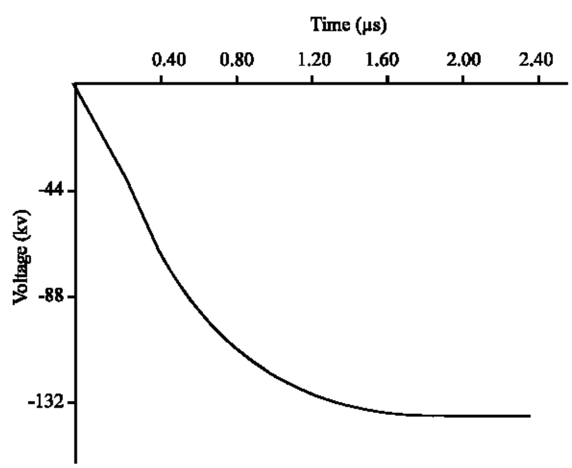

Fig. 4: Form of feigned wave

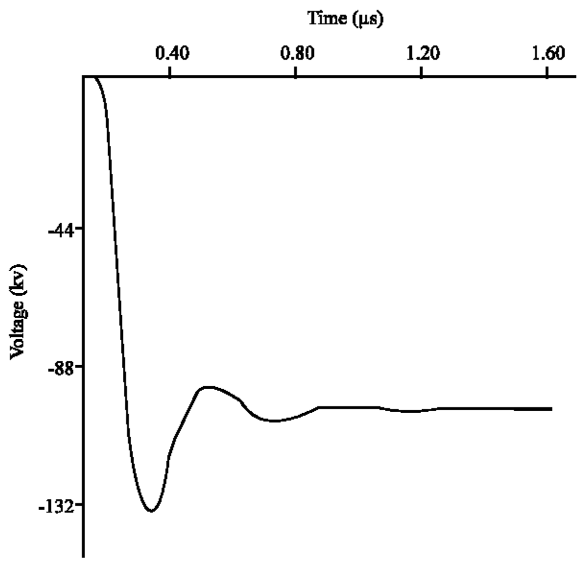

Fig. 5: Form of wave simulated with steep front

The purpose of this job is precisely to search a model representing the behavior of the braid which can be to adapt to program.

DEVELOPMENT OF A PHYSICAL MODEL FOR THE BRAID

Choice of the model: According to the form of the braid (Fig. 1), they see apparently that there is a coupling capacitive not only between the braid and the mass of the system, but also between the sons of the braid. Therefore they are led to consider the braid to be a line, with the only difference that there is a longitudinal capacity to take into account electrical coupling between the sons of the braid (Heller and Veverka, 1968).

One chosen therefore as a basic stitch of the braid the schema of Fig. 6.

k : Longitudinal capacity per unit of length.
c : Transverse capacity per unit of length.
L : Inductance per unit of length.
• : Résistance per unit of length.

The application of the laws of Kirchoff in the basic stitch allows us to acquire the following system (Philips and Taylor, 1973):

$$\frac{\partial i}{\partial x} = -c\frac{\partial U}{\partial t}$$
$$\frac{\partial U}{\partial x} = -(i - i_k)\gamma - L\frac{\partial(i - i_k)}{\partial t} = -\gamma i - L\frac{\partial i}{\partial t} + \gamma i_k + L\frac{\partial i_k}{\partial t} \quad (3)$$
$$i_k = \frac{k}{dx}\frac{\partial(-dU)}{\partial t} = -k\frac{\partial^2 U}{\partial x \partial t}$$

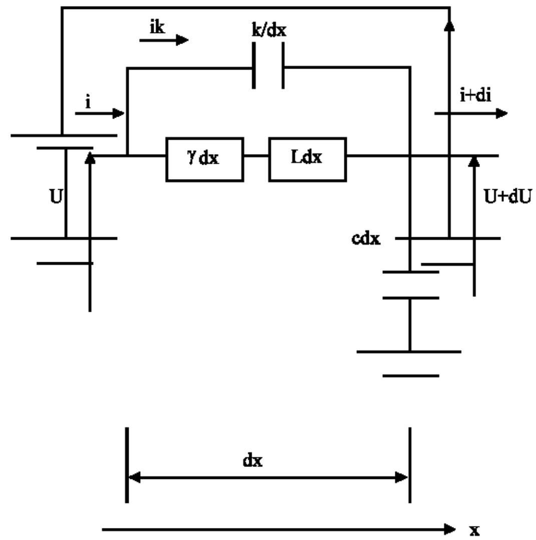

Fig. 6: Schema of the basic stitch of the braid

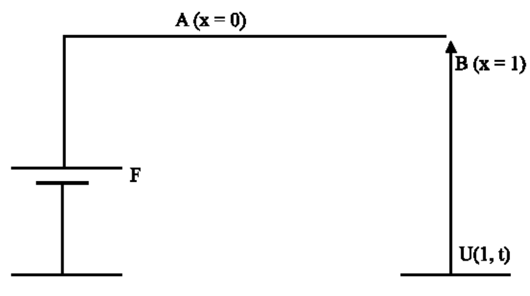

Fig. 7: Schema of analytical counting of the braid

According to which they can find:

$$\frac{\partial^2 U}{\partial x^2} - Lc\frac{\partial^2 U}{\partial t^2} + \gamma k\frac{\partial^3 U}{\partial x^2 \partial t} + Lk\frac{\partial^4 U}{\partial x^2 \partial t^2} - rc\frac{\partial U}{\partial t} = 0$$
$$\frac{\partial^2 i}{\partial x^2} - Lc\frac{\partial^2 i}{\partial t^2} + \gamma k\frac{\partial^3 i}{\partial x^2 \partial t} + Lk\frac{\partial^4 i}{\partial x^2 \partial t^2} - rc\frac{\partial i}{\partial t} = 0 \quad (4)$$
$$\frac{\partial i}{\partial x} = -c\frac{\partial U}{\partial t}$$

Analytical counting of index answer: They developed a model of the braid according to expression (4), however, they cannot use directly equations in stemming partial for numerical simulation. Nevertheless to know the basic number of stitch necessary for the presentation of the braid, they are analytically going to calculate the index answer of the braid in opened circuit (Fig. 7).

$$E = \begin{cases} 0(t \le 0) \\ 1(t \ge 0) \end{cases} \quad (5)$$

AB : Represent the braid.

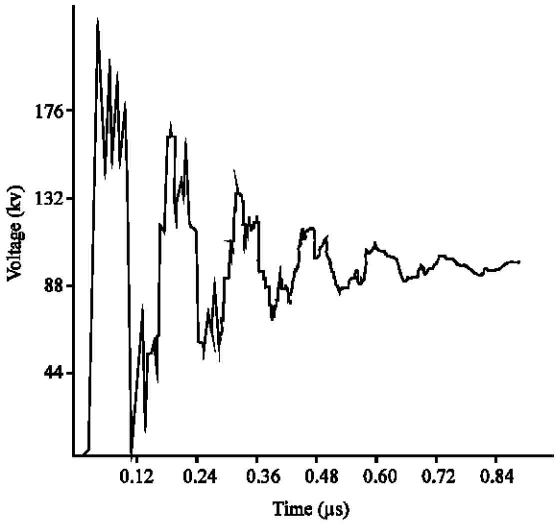

Fig. 8: Index answer analytical

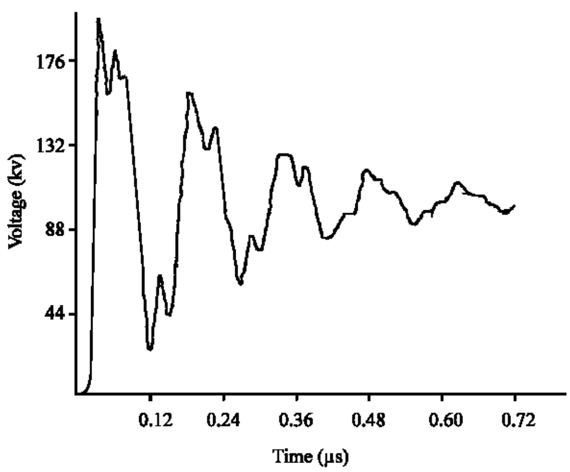

Fig. 9: Feigned index answer simulated (model of the braid 5 cells)

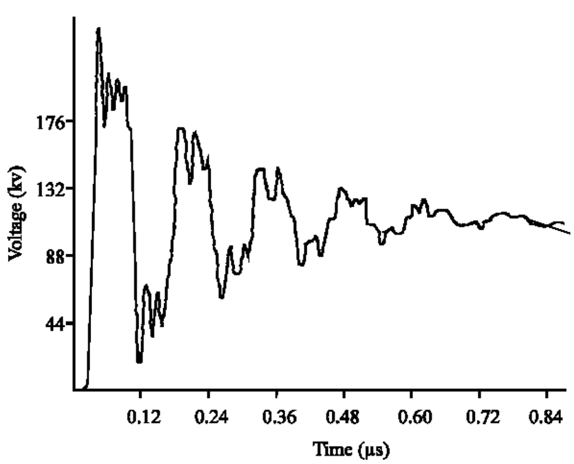

Fig. 10: Feigned index answer simulated (model of the braid 14 cells)

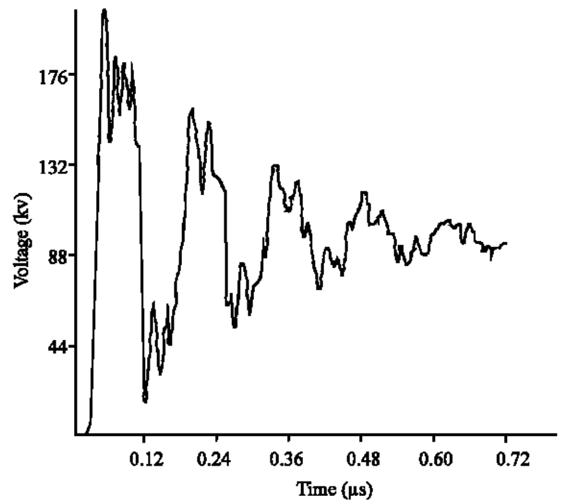

Fig. 11: Feigned index answer simulated (model of the braid 18 cells)

We fetch the voltage U (l,t) by using the method of the separable variables to be able to resolve the system (4). Finally, the index answer is:

$$U(x,l) = 1 - \frac{4}{\pi} e^{\frac{-e}{2L}t} \sum_{n=0}^{\infty} \frac{(-1)^n}{2n+1}\left(\cos\omega_n t + \frac{e}{2L\omega_n}\sin\omega_n t\right) \quad (6)$$

where

$$\omega_n = \sqrt{\frac{\pi^2(2n+1)^2}{L\left(\pi^2(2n+1)^2\kappa+4cl^2\right)} - \frac{(e)^2}{2L}} \quad (7)$$

This index answer is represented to the Fig. 8.

Simulation of the index answer: According to the dimension of the braid of the laboratory (length of the driver l = 60 m, height in comparison with the mass h = 4.0 m,) and the resistance given by the producer, parameters of the braid estimated are: • = 3.50 • /m; L = 0.40. $10^{\bullet 6}$ H/m; k = 0.764. $10^{\bullet 11}$F/m ; c = 9.08.$10^{\bullet 13}$ F/m.

Simulation is made by program by taking a circuit with constant located composed of several serial cells and it to represent the braid. Figure 9-11 show the feigned index answers acquired respectively with a circuit composed of 5.14 and 18 cells. It comes out again from it that of course the increase among cells ameriorates simulation, but the number of elements of the model. Seen that difference enters represent them 10 and 11 is not important, so they take the circuit of 14 cells (Fig. 10) to represent the braid as a good compromise.

EXPERIMENTAL VALIDATION OF THE MODEL

This experience consists in raising the index answer of the braid in well definited conditions. The braid is put in about 50 cm above the plan of shock, they apply an echelon of voltage to one of its ends by making a short-circuit with the aid of an intermediary with contact in quick silver.

The laboratory answer of exit of the braid is shown in the Fig. 12, while Fig. 13 show the answer simulated by program with identical circuit.

There exists good correlation between the laboratory answer and the answer simulated by program with identical circuit, Fig. 12 and 13 shows results.

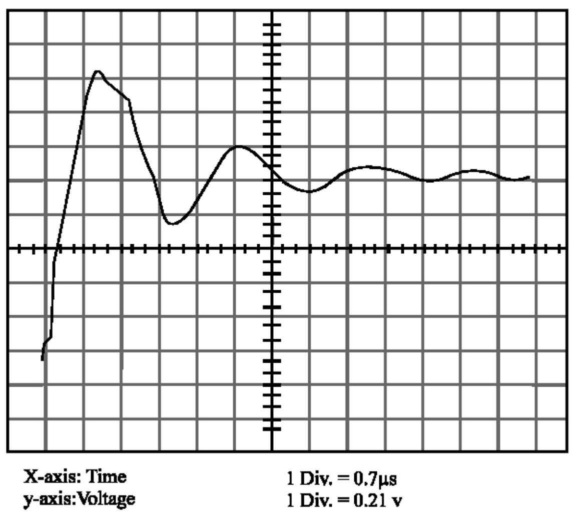

Fig. 12: Answer of exit of the braid measured in laboratory

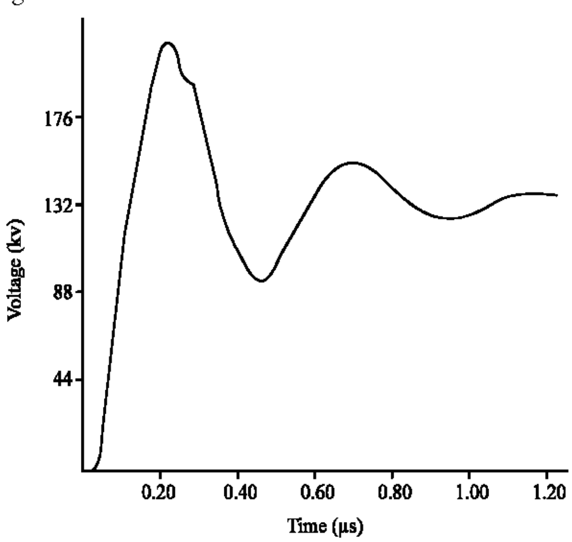

Fig. 13: Answer simulated by program with identical circuit

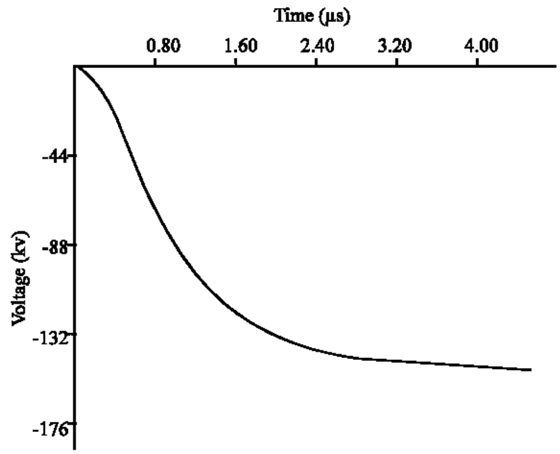

Fig. 14: Form of wave simulated (model of the braid 14 cells)

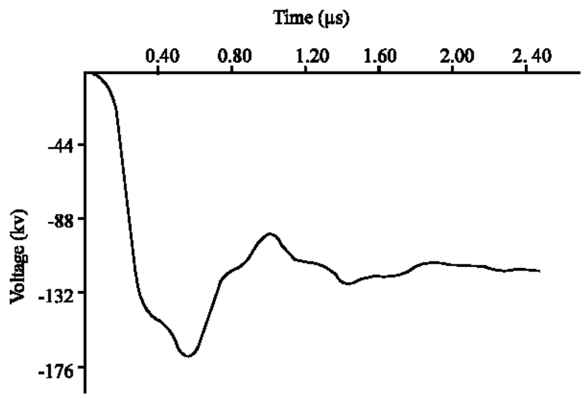

Fig. 15: Form of wave simulated (model of the braid 14 cells) in steep front

To validate this model of the braid well, they make a simulation of the trial system in its entirely by using this model with different forehead of the wave. Figure 14 and 15 shows results.

CONCLUSION

The program which was developed, although comparatively simple allows shocks of voltage a very good approach of the behaviour of the whole installation of try.

The results of simulation are in very good agreement with experimental noting down.

The model of braid which was developed is adapted well by program of simulation. The use of this model returns more definite simulation especially when the front of wave is very rigid.

The reduction of time of rise of the feigned waves (very broadly lower in the nanosecond) is going to require a more and more fine modelling of the equipment.

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