Simulation and tests on surge arresters in high-voltage laboratory

R.Díaz, F. Fernández, J. Silva
High-Voltage Laboratory, National University of Tucuman, 4000 Argentina.
rdiaz@herrera.unt.edu.ar

Abstract - **High-voltage impulse generator is standard equipment in high-voltage laboratories where it is normally used for dielectric tests on power apparatus and equipment. Flexibility to carry out several kind of test for industrial services and applied research is suitable for general-purpose laboratories. In this way, computational simulation of devices and equipment is a useful tool for optimizing test capabilities of such laboratories.**
This contribution relates our experience in application of an h-v impulse generator as an impulse current generator for standard tests on metal-oxide surge arresters in the lower range of distribution voltage. The impulse current attainable with the generator and the measuring procedure were simulated modeling the generator circuit and the non-linear load of arresters by the Alternative Transient Program (ATP) and a simplified version of the frequency-dependent model recommended by the IEEE WG 3.4.11. Tests were performed on metal-oxide surge arresters without information on the residual voltages provided by the manufacturer. Satisfactory agreement is obtained between measurement and simulation, confirming the circuit model and parameters adjustment procedure proposed by the authors and, moreover, it confirms that simulation is useful to improve the laboratory test capacity.

Keywords: Metal oxide surge arrester, High-voltage measurements, Insulation coordination, Modeling.

I. INTRODUCTION

Insulation coordination in electric power systems requires knowledge of the voltage stress wave-shapes. Metal–oxide surge arresters (MOSA) are useful tools for impulse voltage stress limitation. The actual front times of voltage surges are comprised in the order of several microseconds. Surge arrester manufacturers provide information on the residual voltage, limited only up to some surge front times, for current impulses preferably. From this data users should evaluate the performance of surge arresters confronted to various impulse waveshapes. The residual voltages result to be a function of the current peak value and the impulse current rise time. The evaluation of these residual voltages is necessary when accurate insulation coordination is wanted. In this case a combination between experimental procedures and simulation methods should be recommended for obtaining circuital models of MOSA evaluating their performances with several impulse front times, as shown in [1]. The residual voltages on the arrester are calculated for different generator configurations, peak values and front time of current impulses, connecting capacitors in series/parallel groups. The resulting data set is a tool to compose a test procedure in laboratory and simulation helps to upgrade the test circuit. When a high-voltage impulse generator is used in high-current impulse tests, in the order of several kA, special precaution must be paid to avoid very fast reversal voltage in capacitors, which must be much lower than the rated capacitor voltage, in order to extend their lifetime. Another application for this simulation method is to foresee, from few current and voltage measurements in laboratory, the MOSA´s residual voltages for several waveshapes, when the manufacturer´s datasheet is not available.

II. HIGH-CURRENT GENERATION

A ten stages impulse generator of 1 MV, 25 kJ, was connected as a serial RLC circuit on the surge arrester by using an external inductor for impulse current conformation. Fig. 1 shows the circuit sketch. The impulse current attainable with the generator was calculated modeling the circuit by the Alternative Transient Program [2] and the non-linear load of the arresters was simulated with the model and the procedure presented in [1] for fast transient impulses. From Fig. 2 we obtained the calculated results presented in Table 1.

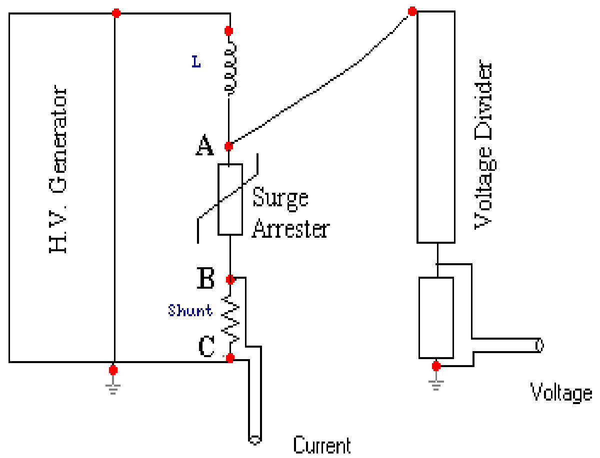


Fig. 1. Test circuit.

Table 1 shows the calculated maximum peak and front time of current impulses on the measuring resistor, and the residual voltage on the arrester, when the generator, connected in a series of two groups consisting of five capacitors in parallel, is charged to 90% of the rated voltage. The resulting data set corresponds to four types of middle-voltage surge arresters and 8/20 µs standard discharge impulse current [3]. From the calculated results it should be expected to use this generator to carry out standard tests on the three first types of arresters.

Table 1

C= 1.25 µF; Rf= 4.8 ohm, Rt= 60 ohm; L= 40 µH

Surge arrester. Reference voltage / current	Peak current [kA]	Residual voltage [kV]	Front time [µs]
12kV / 5kA	12.5	45.7	8.5
30kV / 5kA	6.5	101.0	7.4
12kV / 10kA	12.9	41.8	8.6
30kV / 10kA	7.1	94.9	7.7

III. HIGH-VOLTAGE MEASUREMENTS

Accurate voltage measurement in tests with high-current impulses is a not simple task since induced and resistive voltages may sometimes cause significant errors. The impulse current brings on induced voltages in the voltage measuring circuit, high currents generate non-negligible voltage drops on the measuring shunt and also strong currents should increase voltage in ground connections. In order to avoid mutual coupling between current and voltage circuits, the geometrical disposition of the apparatus and connections must be laid down carefully. In addition, the current circuits, including the earth connection, must have very low impedance. The earth lead of the shunt was directly connected to the ground connection of the generator first stage capacitor.

The above mentioned effects on the voltage circuit were discussed in [4], where a differential test procedure for voltage correction was proposed in order to overcome the requirements of the standard [5] concerning the voltage measurement in high-current test. This procedure is achieved by using digital recorder, which allows performing the numerical difference between voltages measured in both ends of the surge arrester.

IV. HIGH –CURRENT MEASUREMENTS

The current impulse measurements were achieved with a non-commercial squirrel cage shunt resistor of Ni Cr alloy [4]. The values of resistance and inductance measured at 295 K, between d.c. and 100 kHz, were 65 mohms and 30 nH. Consequently the constant time of the shunt resistor was 460 ns. The dynamic behavior was evaluated from a current step response test, which evinces satisfactory response in the nominal epoch for impulses with front time between 2 µs and 20 µs. It also was assessed the linearity and thermal performance [4] of the shunt.

V. MEASUREMENTS AND SIMULATION

When there is a lack of information concerning the residual voltages of a MOSA without the manufacturer’s datasheet, it should be possible to verify the residual voltages for several peak and front time values of current impulses, by using the proposed procedure [1] for parameters evaluation of the IEEE simplified model [6]. Fig. 2 shows the circuital model employed for simulating the experimental set up.

For evaluation of the adjustment method performance, we choose a MOSA of 12 kV, 5 kA rated values provided by a manufacturer not considered in the theoretical evaluation carried out in [1].

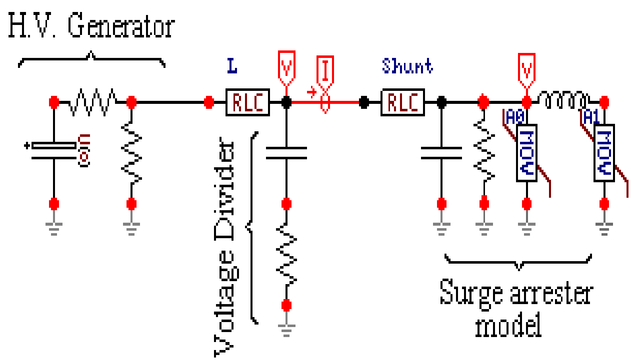


Fig. 2. Circuital model.

Fig. 3 shows the impulse current and residual voltages across the surge arrester measured for three different values of discharge current. This is the experimental data set, which consents to attain the parameters adjustment of the proposed model.

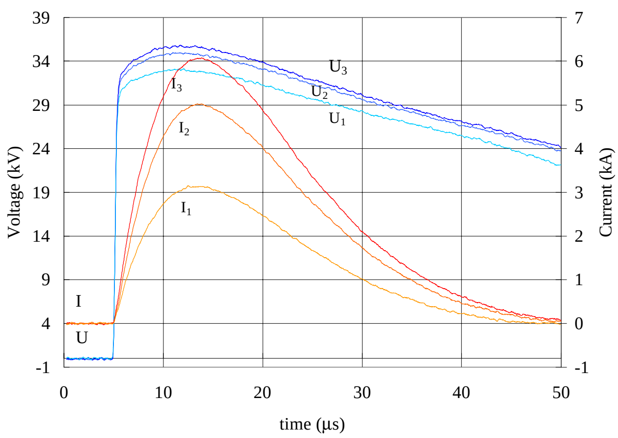


Fig. 3. Measured residual voltages across the 12 kV, 5 kA surge arrester for 8/20 µs impulse current of the following peak values:
I_1 = 3090 A, I_2 = 5000 A, I_3 = 6050 A.

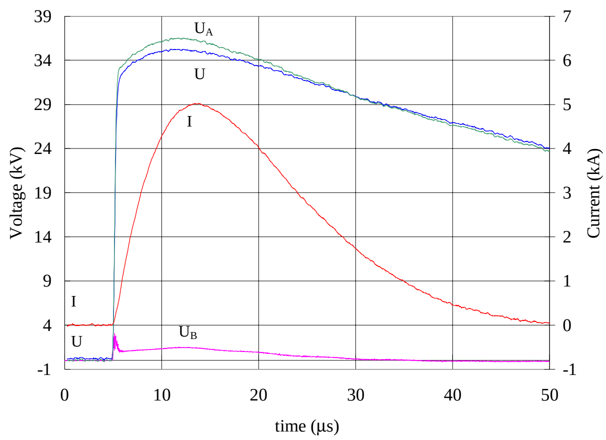
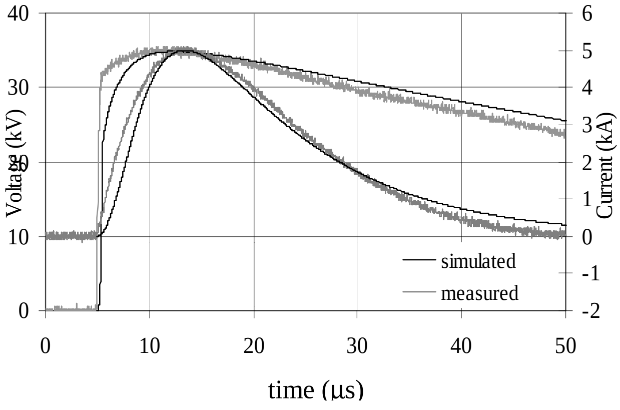


Fig. 4. Measured currents and voltages for a 12 kV, 5 kA MOSA. $U = U_A - U_B$, is the residual voltage.

The residual voltages across the surge arrester were achieved following the measuring procedure presented in [4]. Fig. 4 shows the row data obtained in laboratory, where U_A and U_B represent, as drawn in Fig.1, the voltage measured on the high voltage and low voltage leads of the surge arrester in two successive shots. From Fig. 5 it is possible to compare measured and simulated discharge currents and residual voltages for time fronts of 8 µs and 1.7 µs.

The per-cent differences in the peak value of both current impulses, simulated and measured, are –0.1 % and 1.5 % for 8 and 1.7 µs. Finally, the residual voltage errors between the simulated and measured values are –0.7 % and –1.7 % for the current impulses of 8 and 1.7 µs, respectively. These values are comprised in the order of the total measuring uncertainty (2%). Thereby, for the first waveshape the difference could be considered negligible. For the last case, it should be noted that if a non-negligible error exist; it might be due to the combined effect of uncertainties introduced by the voltage measuring system, the limited dynamic performance of the current measuring system, typically the shunt resistor, and the simplifications assumed in the model [1] when R_0 and L_0 are neglected.



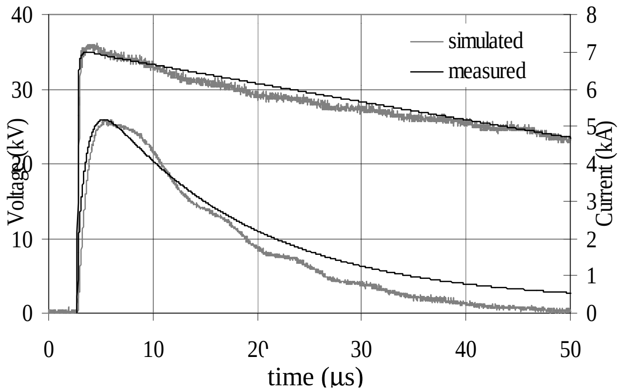


Fig. 5. Measured and simulated residual voltages and discharge currents for 8/20 and 1.7/15 µs impulses.

VI. CONCLUSIONS

The parameters adjustment of the simplified IEEE model [6] was achieved for a MOSA without information furnished by the manufacturer on the residual voltages. Validity assessment of the proposed model [1] was obtained from few tests for discharge currents of 1.7 and 8 µs.

A standard high-voltage generator could be used as a current generator for standard test on MOSA, in the lower range of distribution voltage. Stage connections and impulse currents may be well estimated using computer models.

The restriction of the standard [5], concerning the voltage measurement in high-current tests, may be overcoming by using a differential procedure with digital recorders.

References:

[1] Fernandez F., Diaz R., “Metal-oxide surge arrester model for fast transient simulations“. Paper 144 presented to IPST 2001.
[2] Leuven EMTP Center, "Alternative Transient Program Rule Book", 1990.
[3] IEC 60099-4, “Surge arresters-Part 4”, 1991.
[4] Diaz R., Fernandez F., “High-current tests with an high-voltage generator”, IWD 36 CIGRE WG33.03, Joensuu, 1998.
[5] IEC 60060-1, “High-voltage test techniques - Part 1”, 1989.
[6] IEEE Working Group 3.4.11, “ Modeling of metal oxide surge arresters”, Trans. of Power Delivery, pp. 302-309, 1992.