Complex lightning current simulation in laboratory.

Jan Meppelink*, E.G. Jordan**
*University of Paderborn,
Lübecker Ring 2
D 59494 Soest,
Germany

** BET Blitzschutz-und EMV Technologiezentrum GmbH, Menden.

*Tel.: 0049 2921 81235, Fax. 0049 2921 84263, e-mail: Meppelink@t-online.de

Abstract

Lightning effects technical systems in air as well as on earth. The present knowledge of lightning physics and the actual results of measurements of natural lightning currents are the engineering parameters for the design of aircraft as well as for buildings and systems on earth. These parameters have to be represented in a laboratory in order to test the components and systems, which are affected by lighting currents. The paper gives an overview of all lighting parameters and will show a laboratory technology to simulate all parameters of lightning currents using a crow bar generator for 200 kA, a multiple lightning current simulator for 10 pulses 8/20µs, 40 kA and finally a long duration current simulator for 200 As charge transfer. All these generators can be combined. Samples of tests will be shown and the experience with these generators will be discussed.

1 Introduction

Fig 1 shows a reproduction of a measured negative downward lightning stroke containing subsequent strokes (also called multiple lightning) and a long duration current. The negative downward discharge shows the highest complexity. The discharge starts with a first stroke with a moderate steepness of the current but high current peak. The subsequent stroke shows a much higher steepness of the current but moderate peak values. Due to the physics of the discharge a long duration lightning current can be observed in many flashes. This is a DC component of some 10 A and a duration of nearly one second. The impact of these currents to technical systems is as follows. The current peak causes damages due to magnetic forces and will also create overvoltages on transmission lines. The Charge of the current impulse is responsible for melting of metals when hit by the arc footing point of a stroke. The Action integral is responsible for heating effects. The di/dt values induce overvoltages in adjacent electrical installations. Especially the long duration component is a dangerous event because of its duration. The nature of lightning creates randomly a series of different shapes of current impulses which have been measured /1/. A statistical distribution is shown in Fig.2.

2 Lightning current simulation in laboratory

Lightning currents can be generated e.g. using RLC circuits. Long duration component can be simulated using battery circuits or rotating generators. Standards for lightning current simulation have been recently revised. The first stroke shall be represented using a 10/350µs wave shape with a up to 200 kA peak value, which can be easily generated using a crow bar circuit. However using crow bar circuits only low impedance testing devices are permitted, otherwise the capacitor bank will be very costly. The subsequent stroke is defined by an 0,25/100µs impulse up to 100 kA peak value can be generated using exploding wire circuits as described in /3/.

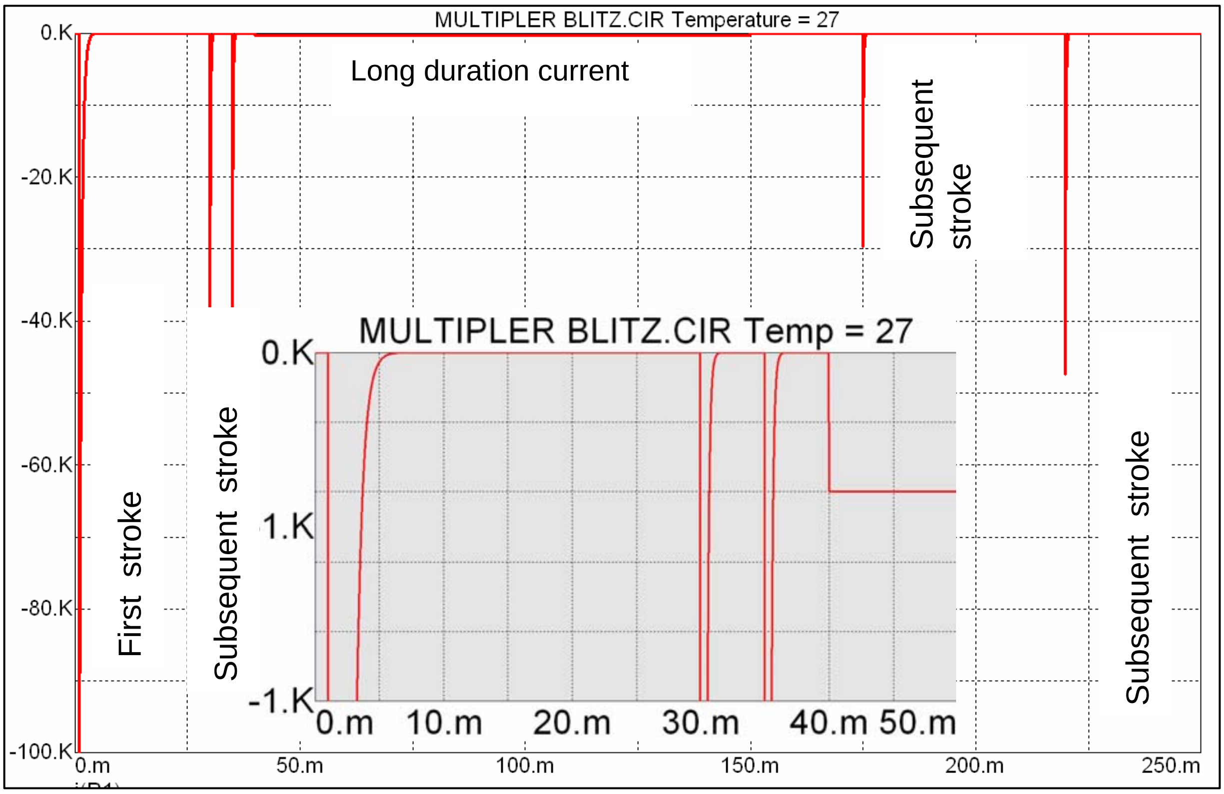

Fig.1 A typical shape of a negative cloud to ground discharge. First stroke: 100 kA. Subsequent strokes of different magnitude, long duration current: 400 A.

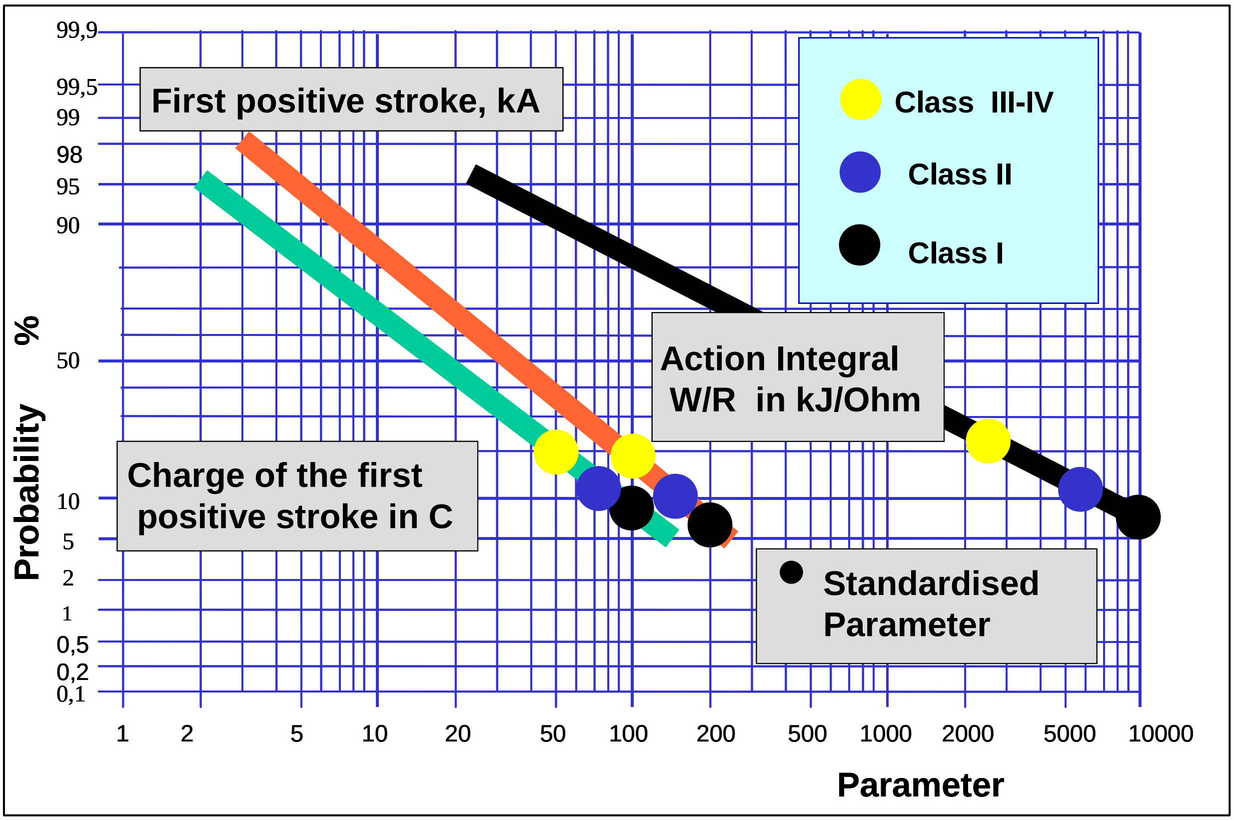

Fig.2 Statistical distribution of lightning parameters according to /2/

The effect of multiple lightning impulse currents to protection devices however can be simulated using a multiple hybrid generator, which generates a voltage surge of 1,2/50µs into an open circuit and an 8/20µs current impulse into a short. In this case the steepness is lower than in original subsequent strokes but the impact on protection devices can be shown e.g. the trigger behaviour.

2.1 Simulation of the first stroke

Fig. 3 shows the basic principle of a crow bar circuit for generation of surges with long time to half value. The upper circuit in fig.3 shows a conventional RLC circuit, which generates an impulse, current with an overshooting behaviour. This is of economic advantage because an oscillating circuit can generate high current peaks. To prevent the continuous oscillation of current and to multiply the charge a crow bar switch is inserted in the lower circuit of fig.3. When the crow bar circuit is triggered the current shape changes from oscillating current into RC-roll of behaviour. Fig 4 shows a complete generator for 200 kA 10/350µs current impulses /4/

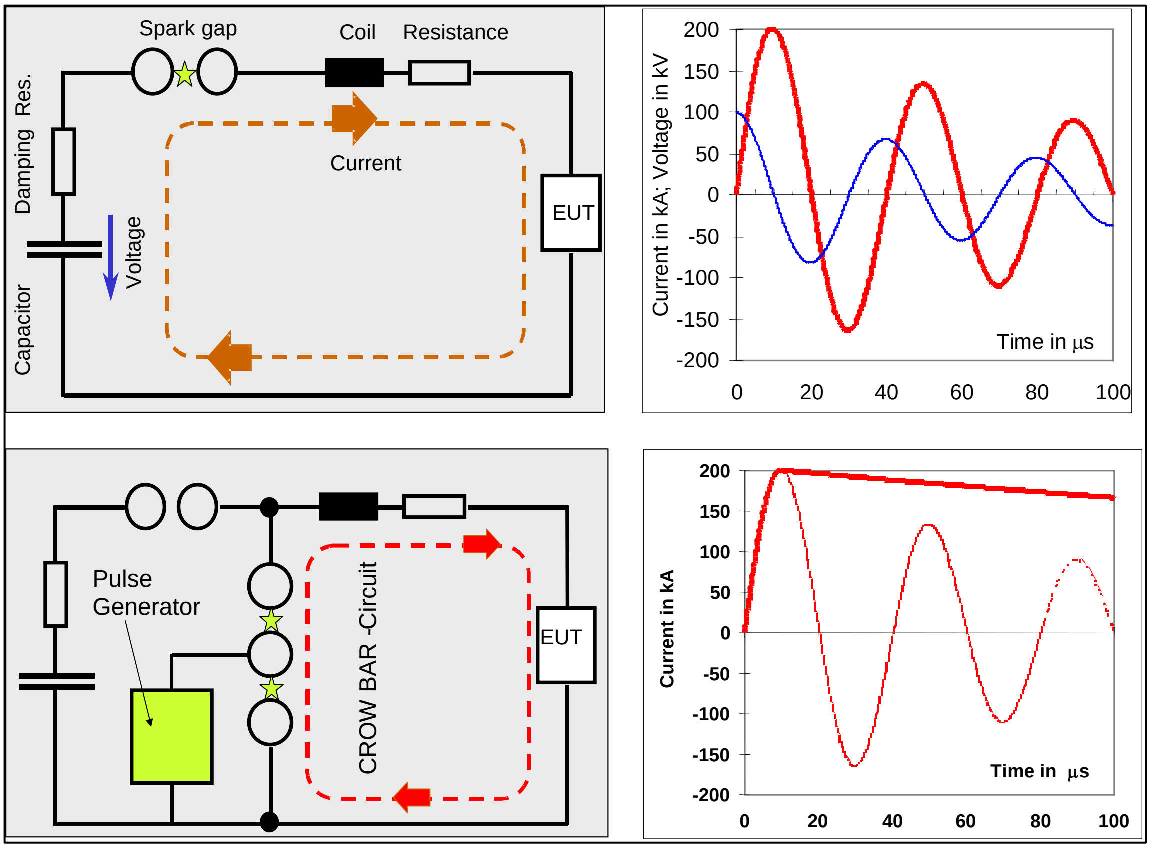

Fig.3 Basic circuit for generation of 10/350µs currents.

2.2 Simulation of the subsequent stroke

A true simulation of one subsequent stroke is shown in /3/. A simulation of multiple subsequent currents using the 0,25/100µs wave shape requires large investments. The impact on surge protection devices can be simulated using a multiple hybrid generator /5/. Fig.5 shows the circuit of a10 stage multiple hybrid generator /5/. The first gap is triggered followed by the other gaps. The plasma of the first current remains in the first spark gap and will be stressed by the overvoltage coming from the second gap. To prevent re-ignition of the first gap, the gaps are cleaned using pressurized air. The recovery time with airflow is less than 5 ms. Fig.6 shows a view of one part of the multiple generator containing 5 stages. Fig 7 shows a test with a surge arrester, which was stressed using 4 current impulses of different magnitude and time interval between the pulses. Using this generator either voltages of 1,2/50µs wave shape or current impulses of 8/20µs wave shape can be generated, each with individual setting of the peak value and each time between two shots can be adjusted using corresponding trigger. Especially surge protective devices can be tested using these wave shapes, since these wave shapes are standardized.

Fig 4 Crow bar generator for 200 kA /4/.

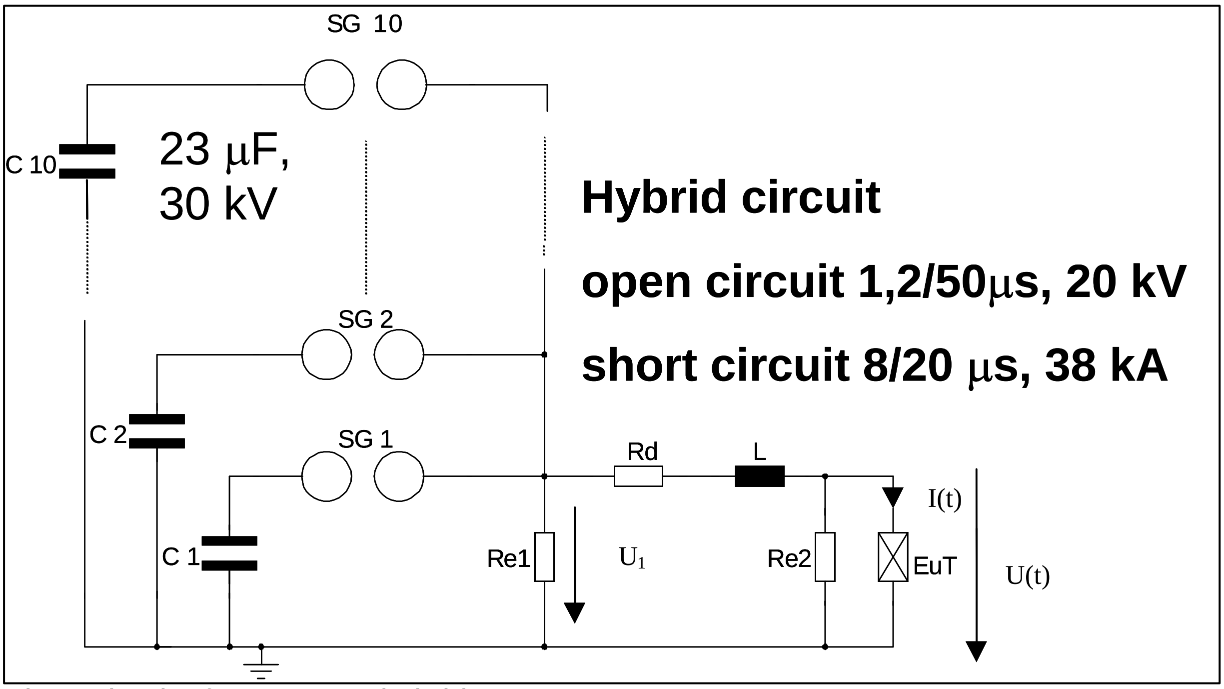

Fig.5 Circuit of a 10-stage hybrid generator.
SG1-10: Spark gaps
C1.C10 Capacitors of the stages
Re1, Rd, Re2, L: Pulse forming elements for hybrid generator
EUT: Equipment under test

Fig.6 view of one part of the generator containing 5 stages.

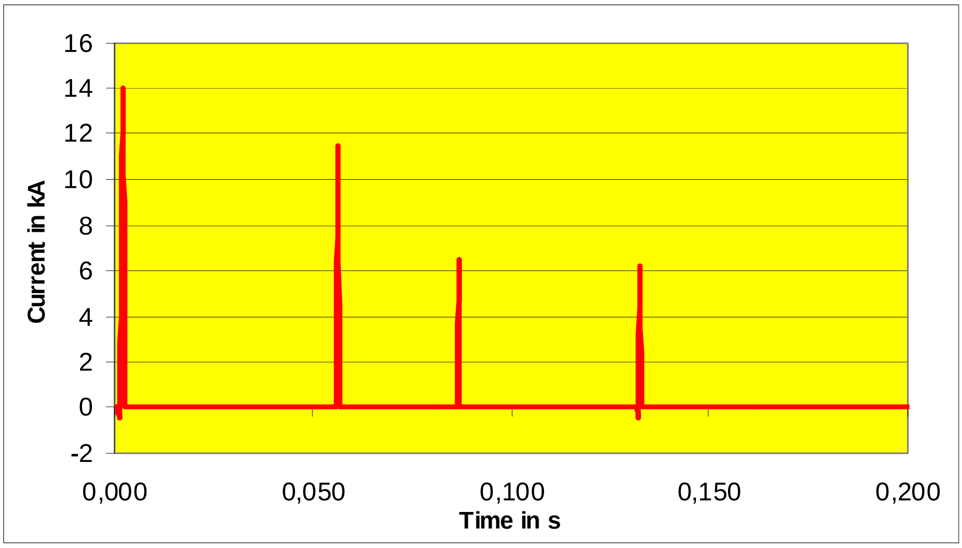

Fig.7 Sample of surge currents applied to a metal oxide surge arrester.

2.3 Long duration current

Long duration currents are defined in standards/2/. The generated charge shall be 100 As or 200 As corresponding to 200 or 400 A for 0,5 seconds. Such currents can be generated using a battery and a DC switch. The decision has to be made for the battery voltage. In some cases an arc shall be generated when testing e.g. the melting properties of metallic surfaces. Therefore a voltage of 870 volt was chosen by the available space for batteries and for economic reasons. Fig. 8 shows a long duration generator. The battery can be switched on and off using an IGBT switch, which is protected using RLC circuits against overvoltages when switching off inductive loads. For the overall protection a 1000 V- DC Power switch and a fuse are installed to protect the battery in case of a short circuit or failure of the IGBT.

Fig.8 Long duration DC-Generator for 870 volt and 500 A.

References

/1/ K.Berger: Novel Observations on Lightning Discharges: Results of Research on Mount San Salvatore. Journ. Franklin Inst.,283 (1967), S. 478-525.
/2/ IEC 61819, TR, ED1: Test parameters simulating the effects of lightning on lightning protection systems (L.P.S.)
/3/ Zischank, W.: simulation of fast rate of rise lightning currents using exploding wires. Proceedings of the 21st International conference on lightning protection, Berlin, Germany, Sept. 21-25, 1992.
/4/ Drilling, C. Droldner, M. Jordan, E.G., Meppelink, J. A NEW GENERATOR FOR TESTING OF SPD`S USING MULTIPLE LIGHTNING CURRENT IMPULSES FOR COMBINED TESTS WITH FOLLOW CURRENTS. Proceedings of the 24th International Conference on Lightning Protection: 14th-18th September 1998, Birmingham, United Kingdom.
/5/ Kallweit, J., Ludewig, S, Meppelink, J., Schoene, J.: Development of a 10 stage multiple lightning surge hybrid generator with variable time interval and peak value. Proceedings of the 24th International Conference on Lightning Protection: 14th-18th September 1998, Birmingham, United Kingdom.