HAEFELY

Actual problems and limitations in measurements with impulse voltage dividers in the multi-megavolt range

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ABSTRACT

A short review of the different possibilities of impulse voltage measurement in the megavolt range is followed by a detailed study of techniques used today.

The different types of impulse voltage dividers are classified and their practical limitations are discussed with respect to the measurement of lightning impulse voltages and switching impulse voltages, as well as the mechanical construction of dividers and the influence of the divider on the impulse wave shape.

As a result it comes out that the damped capacitive voltage divider can be used for two important tasks : the high voltage part of the voltage divider has to be dimensioned according to the requirements with regard to the impulse voltage wave shape, whereas the low voltage part is the essential part for the correct measurement of all impulse voltages.

To fulfill all the requirements of impulse measurements, certain precautions have to be observed. The different influences and some practical limitations are discussed by comparing results of response measurements. Some practical measurements on 5 MV and 6 MV-dividers are given.

INTRODUCTION

In the last 5 years the international recommendations on impulse measurement (IEC 60, 1 to 4) were completed. Special care was given to the accuracy of the impulse measurement. The measurement of the transfer characteristics was specially dealt with.

For practical measurement in any high voltage laboratory the transfer charac teristic of the whole measuring system and the different influencing parameters on it are of interest.

The following report will deal with the practical applicability of the different types of dividers for ultra high impulse voltages. The second part will mention the main influencing parameters on the transfer characteristics of multi-megavolt impulse dividers.

TYPES OF IMPULSE VOLTAGE DIVIDERS

In h.v. impulse measurement we can distinguish nowadays between
- ohmic dividers
- capacitive dividers and
- damped capacitive dividers.

In the UHV-range the damped capacitive divider, consisting of a series connection of resistors and capacitors, is the mainly used design.

For the dimensioning of the measuring system in the UHV-range, at first the total impulse circuit needs to be calculated. Therefore the high voltage part of an impulse measuring system has to be optimized taking into account the requirements with respect to the generation of the desired impulse shapes of the h.v. circuit and the necessary transfer characteristics in order to measure these impulse voltages. Special consideration has to be given to the economics.

The ohmic voltage divider is limited to lightning impulse voltages up to about 2 MV. For the generation of switching impulse voltages the resistance value is too low if the resistor is dimensioned for the measurement of lightning impulse voltages.

The capacitive voltage divider is suitable for switching impulse voltages, but for the measurement of lightning impulse voltages this type of divider cannot be used, because of its tendency to oscillate.

The only type of divider which can fulfill the IEC-requirements in the UHV-range is the damped capacitive voltage divider. This divider can be dimensioned in 3 different types :
- capacitive divider with external damping resistor. This is a solution for the lower voltage range up to 1 MV.
- series connection of resistors and capacitors in the high voltage arm.

The main parameters influencing the transfer characteristics of low damped capacitive voltage dividers are :

- the measuring circuit (horizontal lead, square loop arrangement),
- external damping resistor at the beginning of the lead (three-component system, two-component system),
- impedance of the lead (fig. 4),
- high voltage arm
  - electrodes (fig. 5)
  - active elements
- low voltage arm
  - nominal voltage of low voltage arm (ratio, fig. 6),
  - construction (inductance, coaxial arrangement)
  - elements
  - earthing connections.

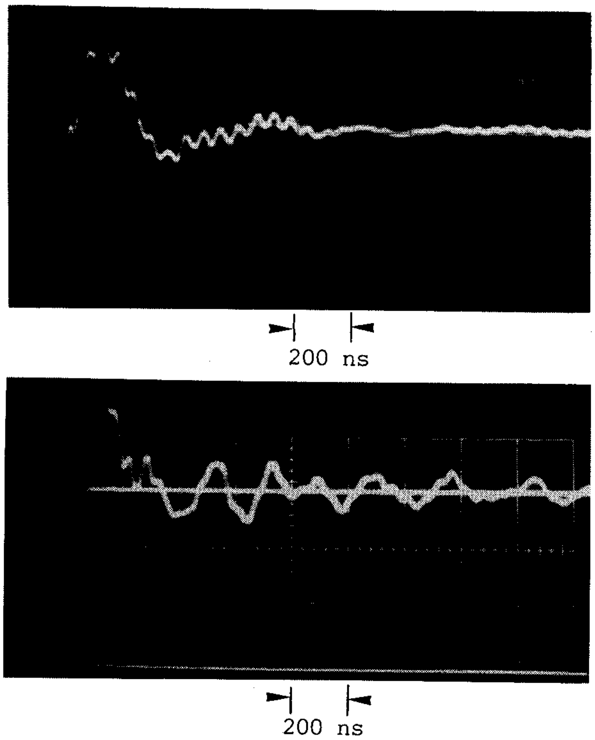

Fig. 4 - Influence of the high voltage lead on the response characteristics of a 3 MV low damped capacitive voltage divider ($C_1 = 187$ pF, $R_1 = 432$ Ω)

a) lead : wire with 1 mm diameter
b) lead : tube with 150 mm diameter.

CONCLUSIONS

The measurement of impulse voltages in the UHV-range needs certain considerations in the design of impulse voltage dividers. It is shown that the high voltage part of a divider has to be optimized with respect to the high voltage circuit and its influence on it, where-

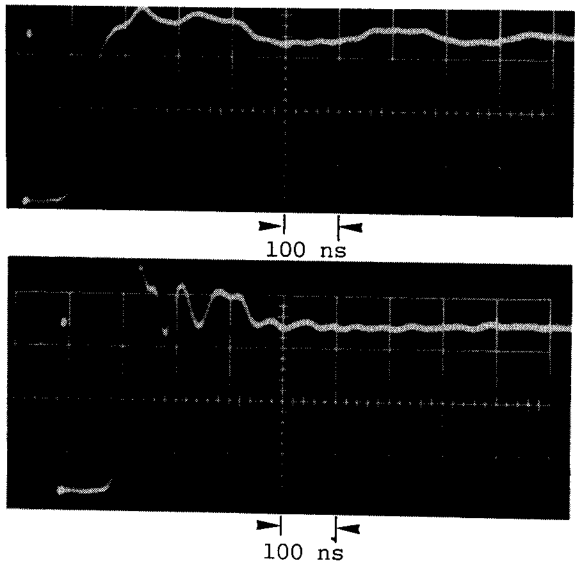

Fig. 5 - Influence of the top electrode on the response characteristics of a 3 MV low damped capacitive voltage divider ($C_1 = 187$ pF, $R_1 = 432$ Ω).

a) with a double toroidal electrode
b) without electrode.

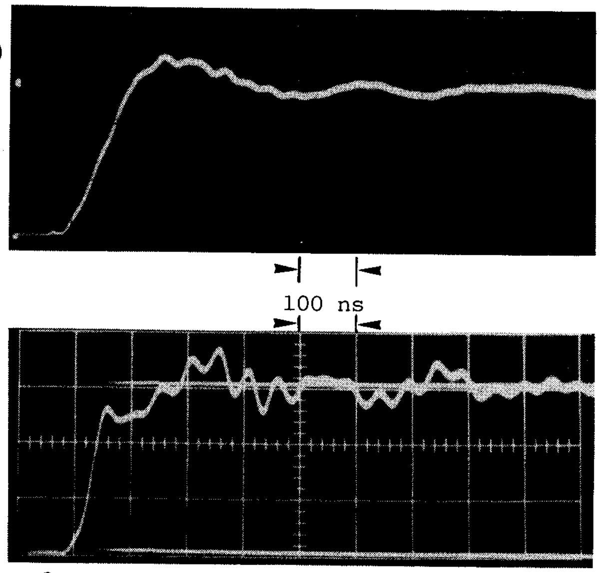

Fig. 6 - Influence of different ratios on the response characteristics of a 3 MV low damped capacitive voltage divider ($C_1 = 187$ pF, $R_1 = 432$ Ω)

a) ratio U_1/U_2 = 762
b) ratio U_1/U_2 = 6420.

as for the measurement of the different test voltages the low voltage part of an impulse divider is the essential element for an optimal transfer characteristic of the divider. In the UHV-region it is possible to fulfill all the requirements with the low damped capacitive voltage divider.

According to the dimensioning of the resistor we can distinguish between
- the optimally damped capacitive divider and
- the low damped capacitive divider.

The optimally damped capacitive divider is intended to be an optimal measuring device, requiring an external damping resistor at the beginning of the lead. Because in the UHV-range this damping resistor is very bulky, the practical applicability of this optimally damped capacitive divider is limited.

The only divider for the UHV-range, which can fulfill the practical requirements of testing with a sufficient performance with respect to the transfer characteristics and the influence of its impedance on the different wave shapes, is the low damped capacitive divider. Therefore in the following we will deal only with the transfer characteristics of low damped capacitive voltage dividers.

TRANSFER CHARACTERISTICS OF DAMPED CAPACITIVE VOLTAGE DIVIDERS IN THE MULTI-MEGAVOLT RANGE

The transfer characteristics of voltage dividers are measured with low voltage using the circuit shown in fig. 1. The most important parameters for the evaluation of the unit step response are
- the start of the unit step response
- the response time T
- the partial response time T_α
- the initial distorsion time T_o.

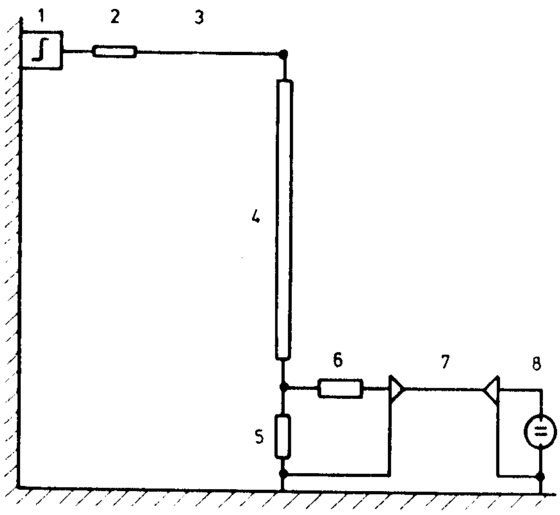

Fig. 1 - Circuit for the measurement of the transfer characteristics of voltage dividers.

The following oscillograms demonstrate the performance of low damped capacitive voltage dividers and show the different possibilities to influence the transfer behaviour.

Fig. 2 shows the transfer characteristics of a 2,4 MV low damped capacitive voltage divider with and without a resistor in the low voltage arm. As can be seen from the oscillogram the resistor in the low voltage arm results in a better high frequency behaviour of the divider.

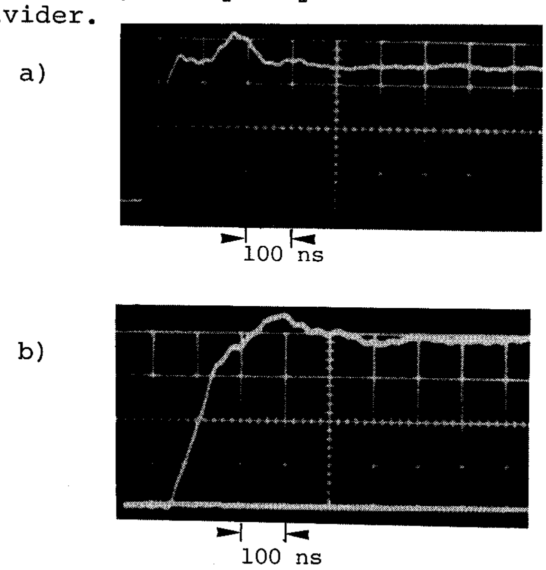

Fig. 2 - Response characteristics of a 2,4 MV low damped capacitive voltage divider (R_1 = 360 Ω, C_1 ~ 300 pF).

a) with R_2 ; b) without R_2.

The same characteristics are shown in fig. 3 for a 6 MV low damped capacitive voltage divider.

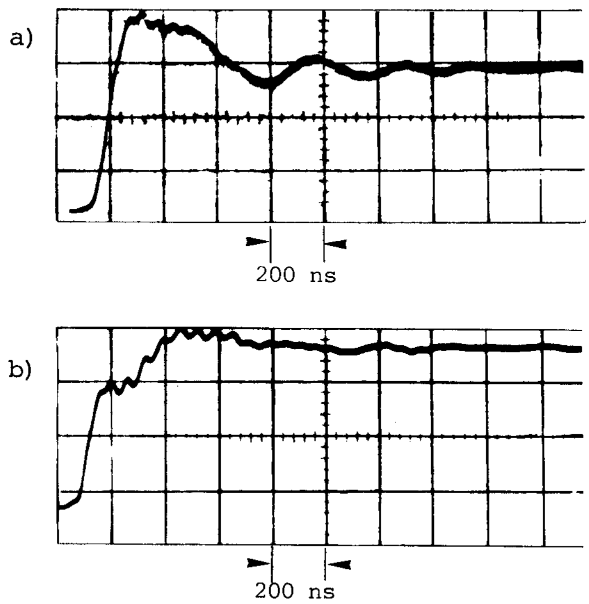

Fig. 3 - Response characteristics of a 6 MV low damped capacitive voltage divider (R_1 = 440 Ω, C_1 = 400 pF).

a) with R_2 ; b) without R_2.