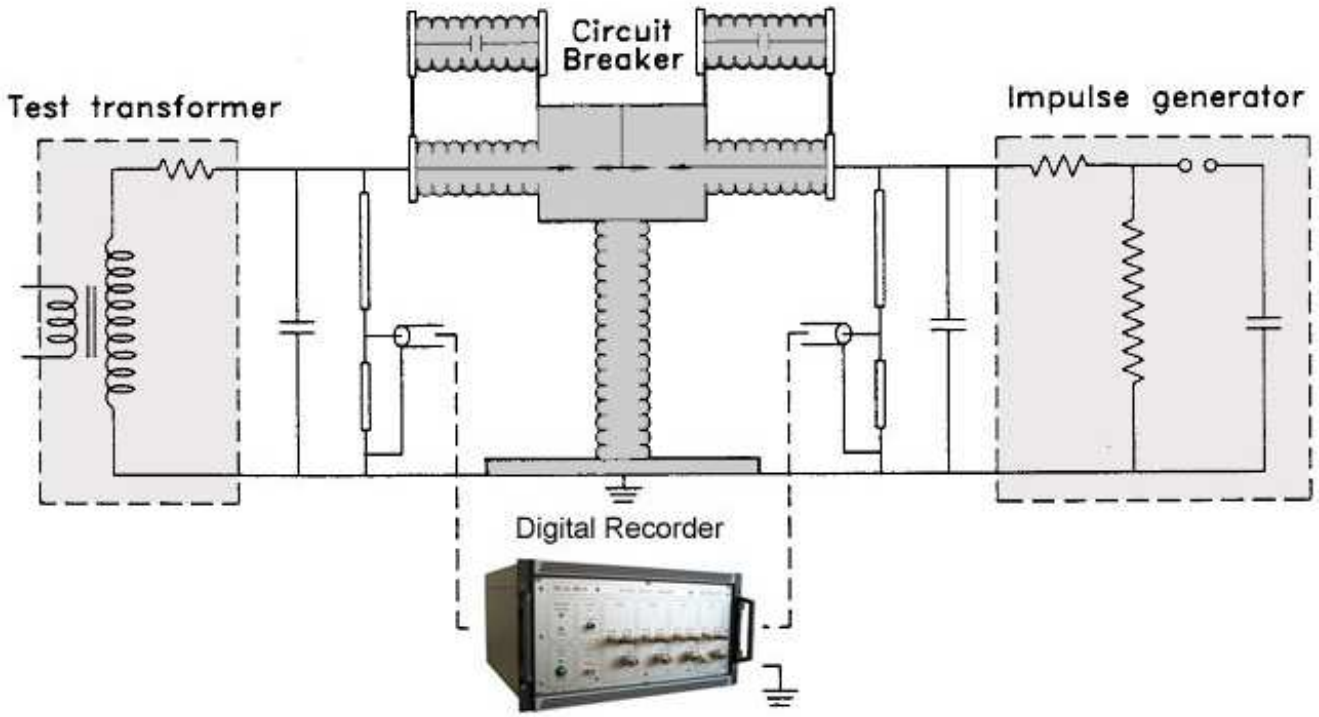
1 Contents



1.1 Example of test circuit for combined voltage tests acc. to IEC 60060-1

2 Combined and composite tests

These tests are described in IEC 60060-1 VOLTAGE TEST TECHNIQUES PART 1: GENERAL DEFINITIONS AND TEST REQUIREMENTS as follows:

2.1 Combined voltage tests

A combined voltage test is one in which two separate sources, generating voltages against earth, are connected to two terminals of the test object, (for example an open circuit breaker, see figure 13a). In such a test any two of lightning impulse, switching impulse, direct or power frequency alternating voltages may be combined.

The test voltage is characterized by its amplitude, a time delay Δt between peaks and by the waveshape, peak value and polarity of each component.

When combined voltage tests are performed on a two terminal test object they are intended to simulate conditions where one terminal of the open switch is energized at the specified power frequency voltage, and the other terminal is subjected to either a lightning or switching overvoltage. The test circuit shall simulate this situation on both internal and external insulation. In special cases the relevant Technical Committee may permit power-frequency voltages to be simulated by switching impulses of suitable shape.

2.1.1 Value of the test voltage, *U*

The value of the test voltage *U* is the maximum potential difference between the energized terminals of the test object (see figure 13b).

2.1.2 Time delay Δt

The time delay Δt of a combined voltage is the time interval between the instants when its components reach their peak values, measured from the instant of a negative peak (see figure 14). It has a tolerance of $\pm 0.05\ T_{pmax}$, where T_p is the time to peak or the front time for an impulse and a quarter cycle for an alternating voltage, and T_{pmax}, is the larger of the values of T_p for the two components.

Two voltages of a combined impulse voltage test are said to be synchronous when their time delay Δt is zero, within the prescribed tolerance.

2.1.3 Actual voltage shapes

Due to the coupling between the two generating systems, the shapes and amplitudes of the two components of a combined voltage test differ from those produced by the same sources used separately. They shall therefore be measured in combination, preferably by means of separate measuring systems against earth.

Each measuring system shall be suitable for measuring the waveshape of both of the components in order to avoid errors in recording their mutual influence.

The maximum permissible deviations from the prescribed voltage shape shall be specified by the relevant Technical Committee.

NOTE: It should be taken into account that in the case of a disruptive discharge occurring in a combined voltage test, both the voltage sources will act directly against each other if there are no additional protective elements (e.g., resistors or protective gaps) in the circuit. In any case the voltage distribution between the two voltage sources will change completely when there is a disruptive discharge.

2.1.4 Arrangement of the test object

The arrangement of the test object, particularly with respect to the earthed structures shall be specified by the relevant Technical Committee.

2.1.5 Atmospheric correction factors

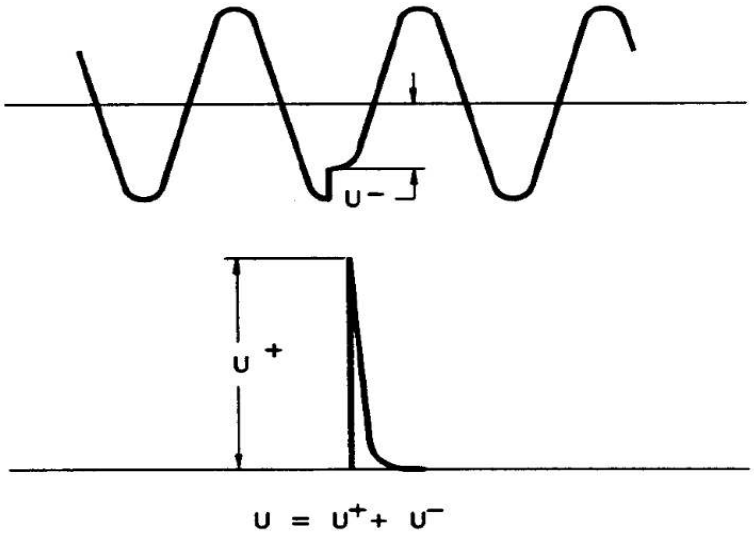
In a combined voltage test, the atmospheric correction factors relative to the component of highest value have to be applied to the test voltage value.

2.1.6 Composite voltage tests

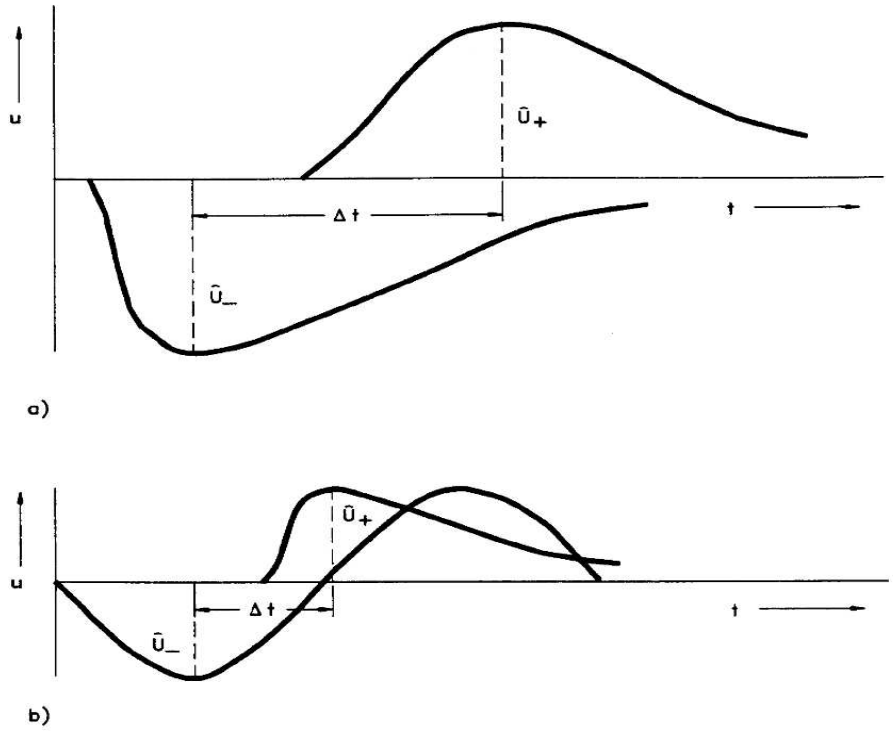
A composite voltage is the voltage resulting from two different voltage sources suitably connected, applied at one terminal of the test object against earth.

The definition of its parameters is left to the relevant Technical Committee.

NOTE: Composite tests may also be performed by applying voltage and impulse-current sources to the test object.



2.2 Example of voltage waves during combined voltage tests giving value of test voltage *U*



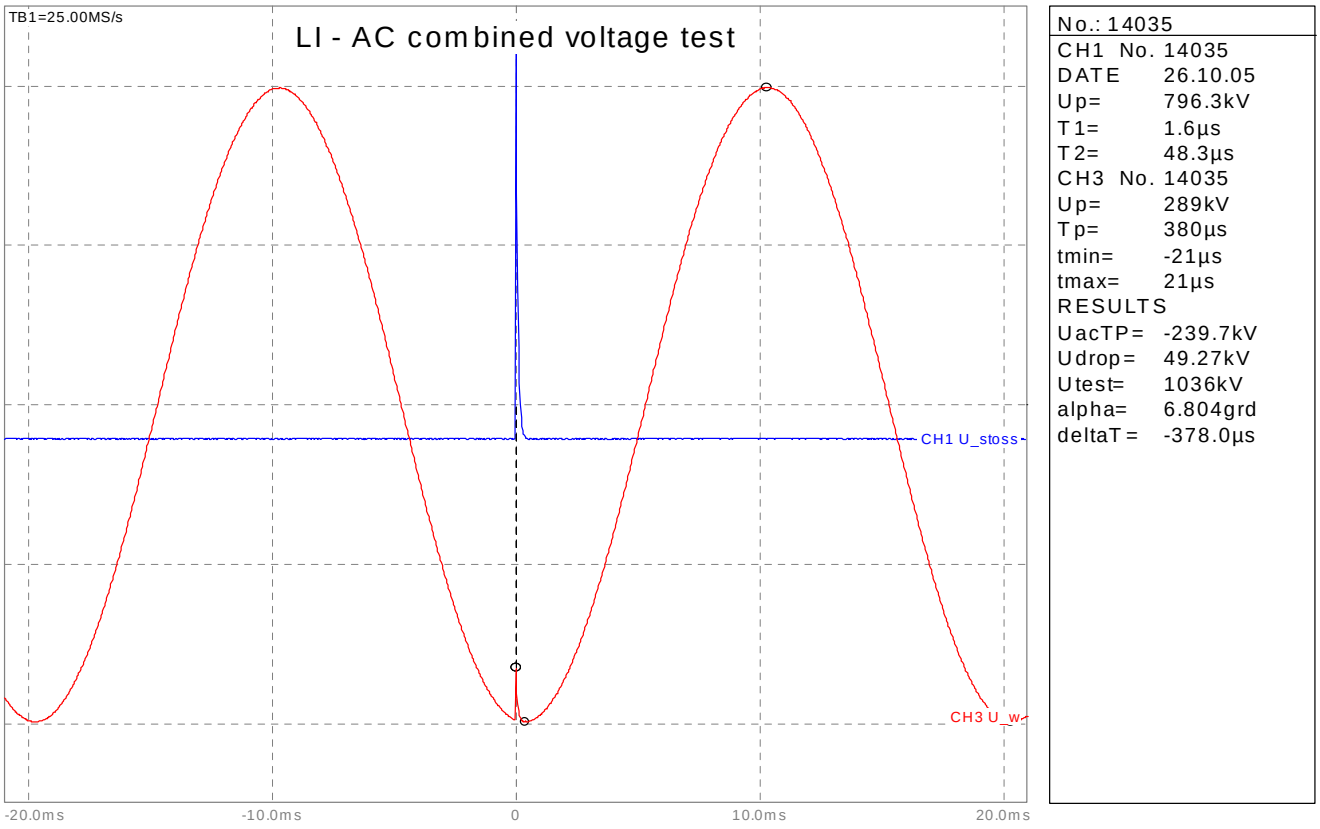
2.3 Definition of time delay Δt

a) Combination of two impulse voltages

b) Combination of an impulse voltage and a power frequency alternating voltage

2.4 Combined Voltage Test with AC and LI

The following documentation was created with help of the WORD-Report Generator of the WinTR-AS software.



Test-2005-10-26 : LI_AC

NO	NO	Up LI [kV]	T1 [µs]	T2 [µs]	Up AC [kV]	UacTP [kV]	Udrop [kV]	Utest [kV]	alpha [°]	deltaT [µs]
1	14035	796,3	1,6	48,3	289	-239.7	49.27	1036	6.804	-378.0

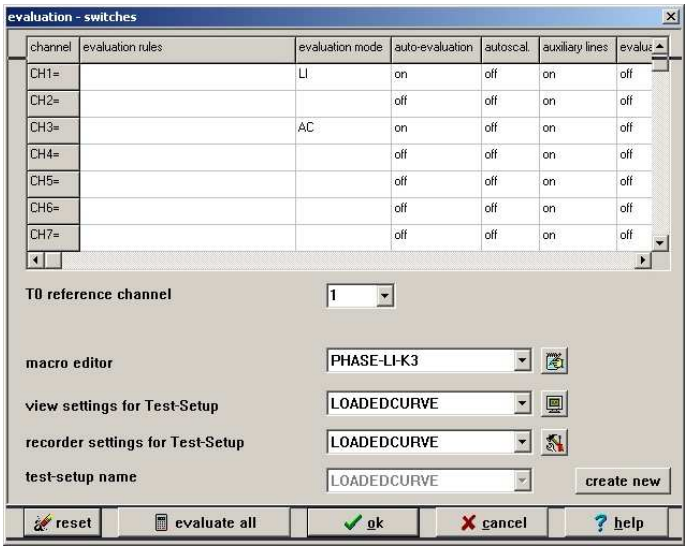
The picture show a combined voltage test with power frequency voltage AC with 289 kV peak and lightning impulse voltage LI with –796.3 kV peak.

With help of the Makro-Editor integrated in the WinTRAS-Software additional test parameters shown under RESULTS in the right evaluation window can be calculated after recording and overtaken into the report generated with the WORD Report Generator automatically:

- the AC voltage at the instant of the LI peak, UacTP
- the voltage drop Udrop of the AC voltage peak with respect to UacTP
- the test voltage Utest as the difference of UacTP and Up of the LI peak voltage
- the time difference deltaT in ms or the angle alpha in degree as the difference between AC peak and LI peak

The respective MAKRO is:

UacTP[kV]=GETMAX(K3,K1_TP,K1_TP)
Udrop[kV]=K3_Up-ABS(GETMAX(K3,K1_TP,K1_TP))
Utest[kV]=ABS(K1_Up)+ABS(GETMAX(K3,K1_TP,K1_TP))
alpha[°]=((K3_TP-K1_TP)/0.02)*360
deltaT[µs]=K1_TP-K3_TP



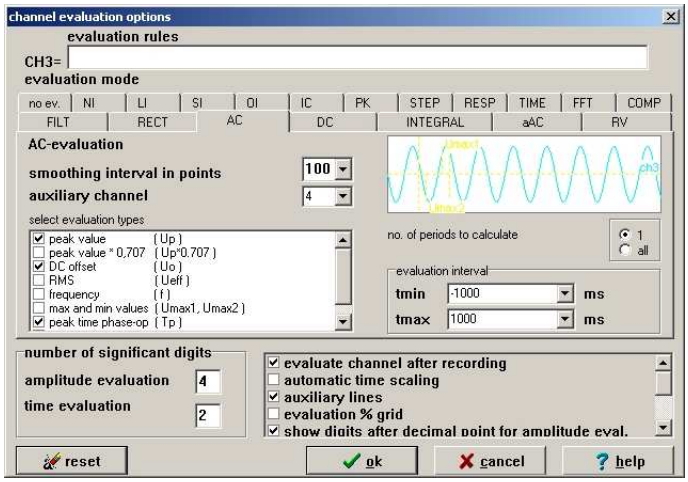
With the evaluation switch formular the evaluation method for each individual channel can be selected.

For channel 1 the selected LI evaluation automatically calculates the peak and time parameter and the overshoot beta.

For channel 3 the AC evaluation was selected.

Furthermore the macro with name PHASE-LI-K3 was selected, details later.

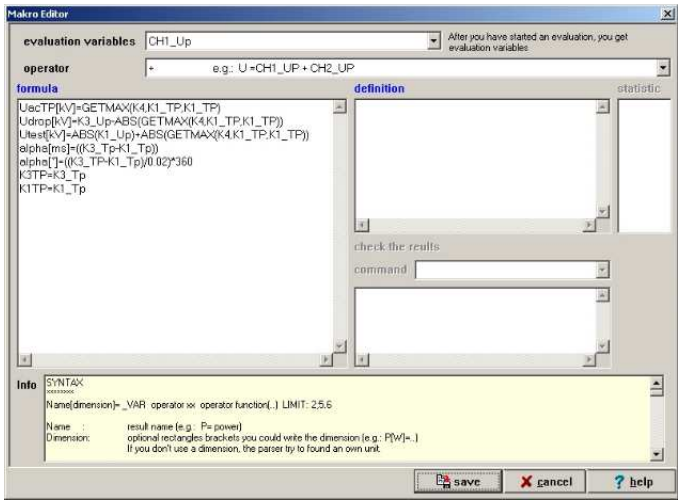
2.4.1 Evaluation selector formular



The AC evaluatin rules were set to peak value and DC offset as also for peak time for phase calculation.

To eliminate digitzer noise the channel 3 is smoothed with 100 samples with help of an virtual auxiliary channel 4 (selectable for further evaluations) and then evaluated in the displayed evaluation interval tmin = –1000 ms to tmax = 1000 ms

2.4.2 Evaluation rules formular



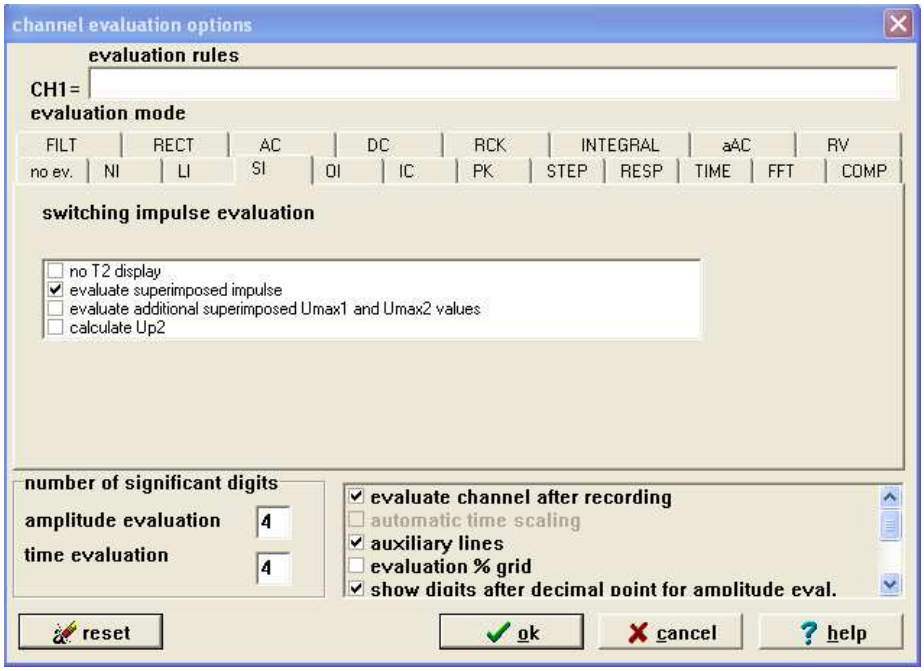
The Makro Editor allows definition of MAKROS which contain expressions with reference to evaluation results of the basic evaluations.

The expressions can be input in the formula field line for line, the variable names can be named free.

This expressions are evaluated immediately after the basic evaluations are performed and then the results are shown in the evaluation window under RESULTS.

2.4.3 Macro Editor formular

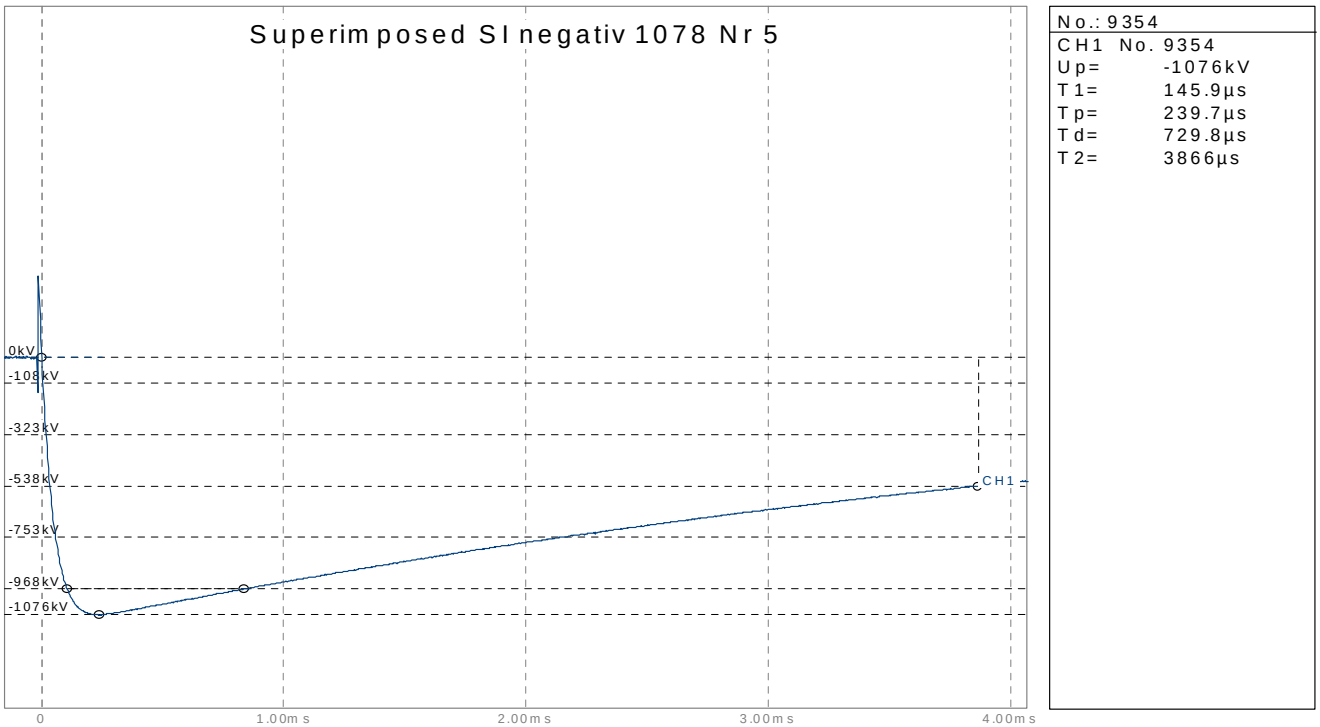
2.5 Composite (superimposed) Voltage Test on H.V. Cables with D.C. and SI



Evaluation settings for superimposed voltage and initial peak amplitudes can be selected

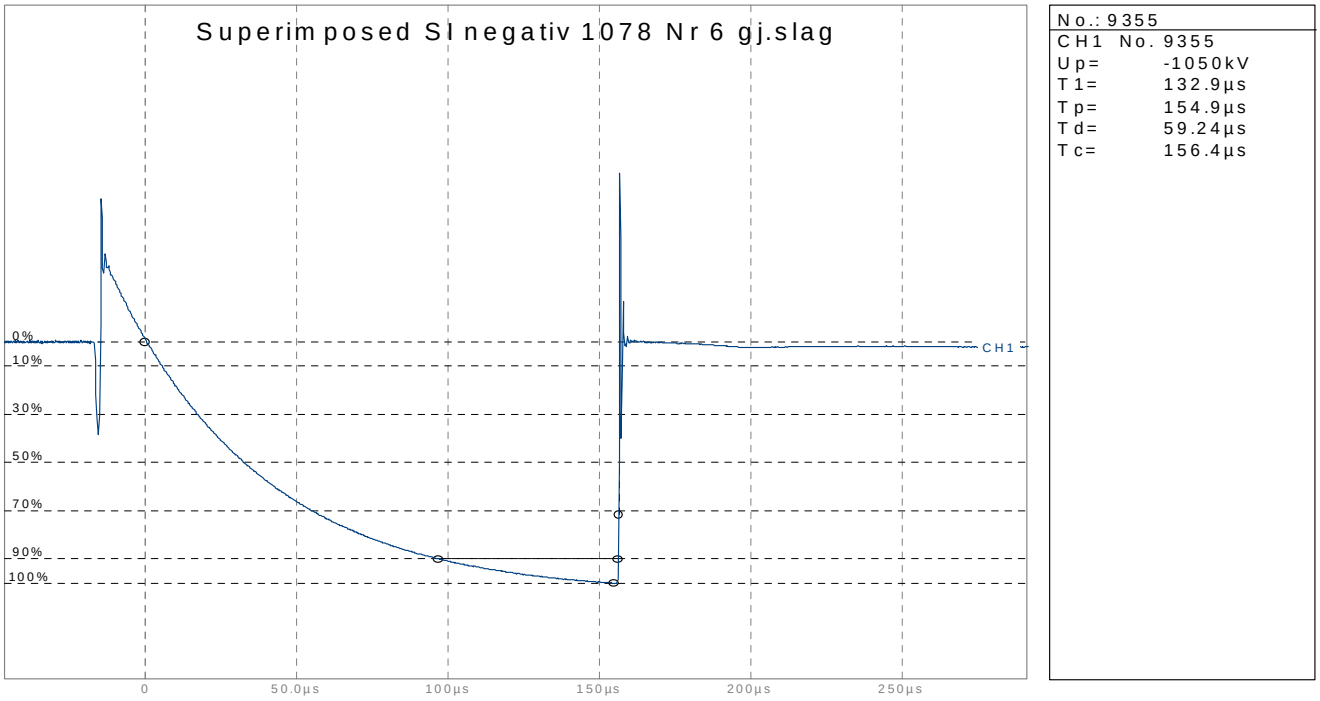
2.5.1 Evaluation settings

CableTest01 : SI							
NO	NO	Up LI [kV]	TP	T1 [µs]	T2 [µs]	TD [µs]	TC [µs]
1	9354	-1076	239,7	145,9	3866	729,8	
2	9355	-1050	154,9	132,9		59,24	156,4



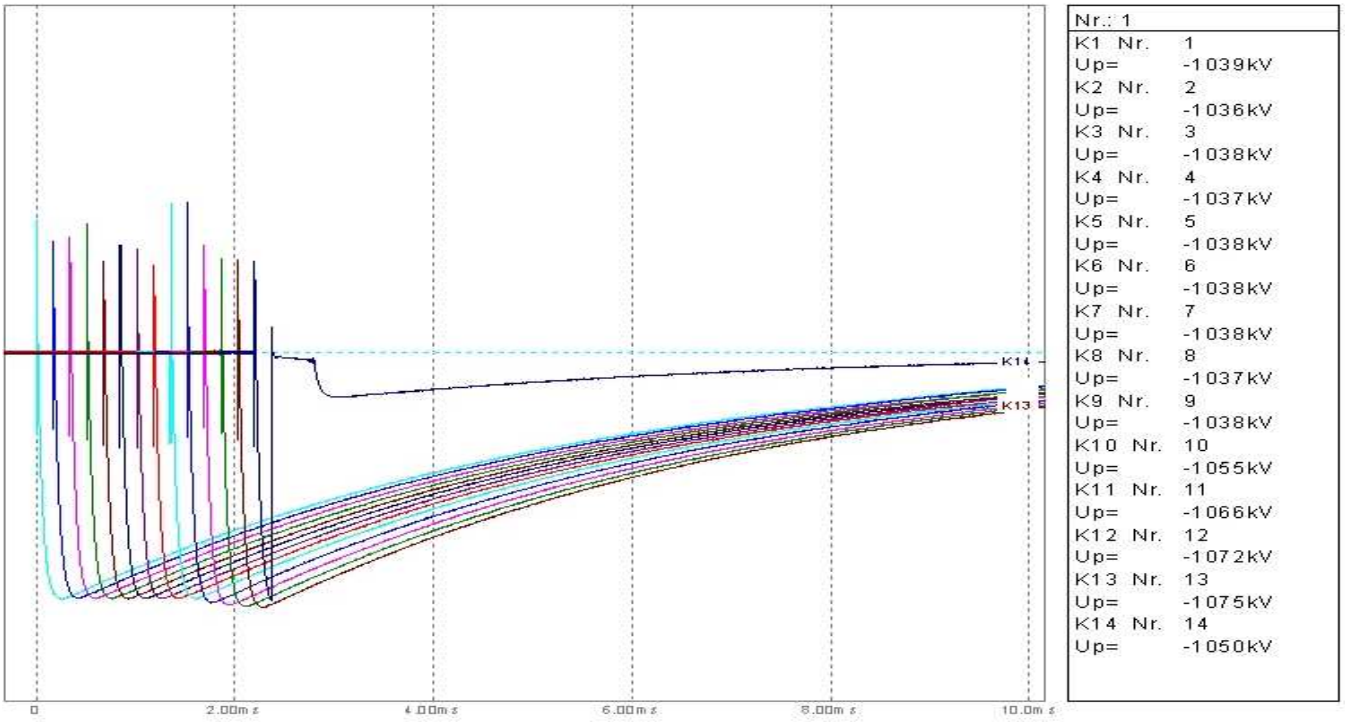
2.5.2 Superimposed voltage test on H.V. Cables with D.C. and SI

with nominal -1078 kV switching voltage



2.5.3 Breakdown of SI test voltage

with nominal -1078 kV switching voltage



2.5.4 Waterfall diagramm of superimposed voltage test on H.V. Cables with D.C. and SI

The picture show a superimposed voltage type test with direct voltage d.c. and superimposed switching voltage SI displayed as waterfall diagramm with selectable No. of shapes, e.g. 14 shapes with horizontal offset of 4%.

The shapes can be preselected and moved horizontally and vertically with selectable offset values.

The test voltage was increased starting with No. 11 and the breakdown occurs with No. 14.