Practical measurements and IEC/EN 61000-4-11

- rise and fall time during short-circuits at different places of a supply installation

The relating standards:
IEC/EN 61000-4-11
IEC/EN 61000-2-8

The part IEC/EN 61000-4-11 of the international IEC/EN 61000 series standards defines test methods for immunity testing and test levels for voltage drops, short interruptions and voltage variations. The standard is applicable for devices intended to be connected to the public low power distribution network. The generation of voltage drops the IEC/EN 61000-4-11 specifies and requires a voltage source with a rise- and fall-time of 1-5µs at 100Ω load.

At a nominal voltage of 230V this means: $230V_{eff}$/µs up to $46V_{eff}$/µs (=325V/µs up to 65V/µs).

The basics about the arising, the effects, remedial actions measuring methods and measurement results of devices to be tested according to IEC/EN 61000-4-11 are defined in the IEC/TR 61000-2-8 Ed. 1.0. The disturbances are described as phenomena appearing on public low voltage supply networks and having influence on devices connected to this public grid.

This document shall demonstrate, that practically the rise- and fall-times of the supply voltage are in the range of 15µs (as described in the IEC/EN 61000-4-11 in the chapter A2: requirements of the voltage source).

One of the main reasons for voltage dips and short interruptions on the public supply network are electric short-circuits occurring on any point of the supplying grid.

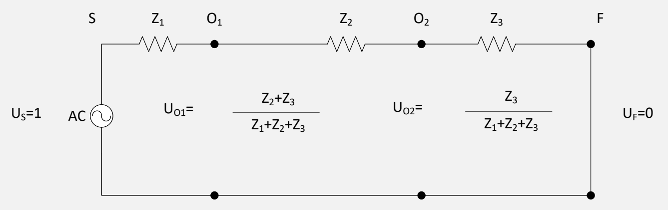

Fig. 1: Equivalent circuit for voltage drops acc. to IEC/EN 61000-2-8

Output voltage at no load: ± 5% of the residual voltage value	
Voltage change with load at the output of the generator:	
100% output, 0A to 16A *80% output, 0A to 20A* *70% output, 0A to 23A* *40% output, 0A to 40A*	*< 5% U_T* *< 5% U_T* *< 5% U_T* *< 5% U_T*
Output current capability: *$16A_{rms}$ per phase at U_{rated}.* *The generator must be able to deliver:*	*20A at 80% U_{rated}. for 5s* *23A at 70% U_{rated}. for 3s* *40A at 40% U_{rated}. for 3s*
Peak inrush current capability: *Not to be limited by the generator*	*Max. 1000A for 250-600V mains* *Max. 500A for 200-240V mains* *Max. 250A for 100-120V mains*
Instantaneous peak overshoot/ undershoot of the actual voltage	*< 5% U_T* *Generator loaded with 100Ω resistive load*
Voltage rise (and fall) time t_r (and t_f) during abrupt change	*Between 1µs and 5µs* *Generator loaded with 100Ω resistive load*
Phase shifting:	*0°-360°*
Phase relationship of voltage dips and interruptions with the power frequency	*<± 10°*
Zero crossing control of the generator:	*± 10°*
Output impedance	*Predominatly resistive < (0,4+j0,25)Ω* *Even during transitions*

Table 1: Requirements of the testing voltage source acc. to IEC/EN 61000-4-11

In electrical systems short circuits cannot be avoided at all. The amplitude of a voltage drop depends on the distance between monitoring point, short-circuit point and supplying source. This relation is shown in Fig. 2. To meet the practical values described in the technical report IEC/TR the requirements of the testing voltage source of the IEC/EN 61000-4-11 are well defined in table 1.

The theoretical values for rise- and fall-time can be calculated by simulation software. For this simulation the parameters for the cable length must be calculated. The definition of the equivalent circuit was given as a short circuit at the load, at the local grid entry point and within the local grid.

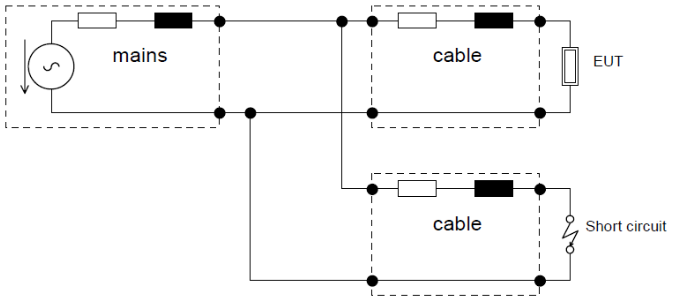

Fig. 2: Equivalent circuit diagram for short circuit in the supply line

The base impedance for the simulation is the mains reference impedance defined in the IEC/EN 61000-3-3 with 0,4+j0,25 Ohm. The simulation performed the characteristic of a resistive load with 16A nominal current at a nearby (20m) occurring short circuit (with a cable diameter 1,5mm²).
The rise- and fall-times of the supplying voltage at short circuit are shown in Fig. 3. And Fig. 4.

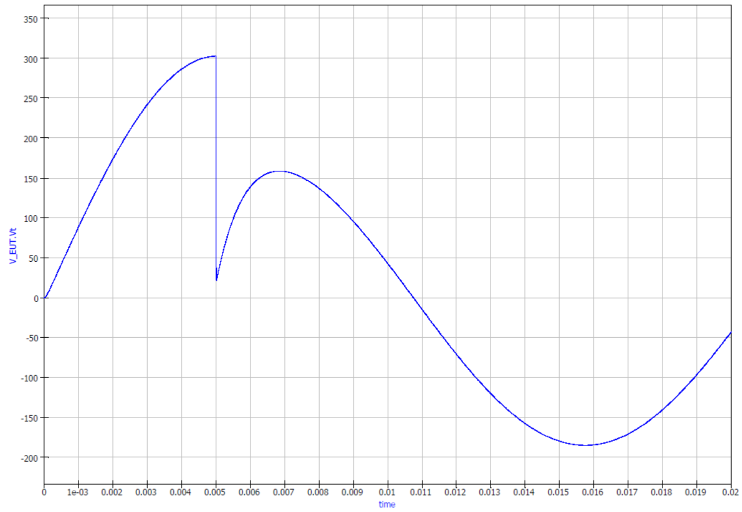

Fig. 3: Voltage characteristic during simulation (1ms/DIV)

In Fig. 4 (higher resolution in the time base) the fall-time of the supplying voltage can be seen in a range of 5µs.
To verify the simulated values with the rise- and fall-time of the reality several practical measurements have been performed.
The measurement results were then compared with the simulation results.

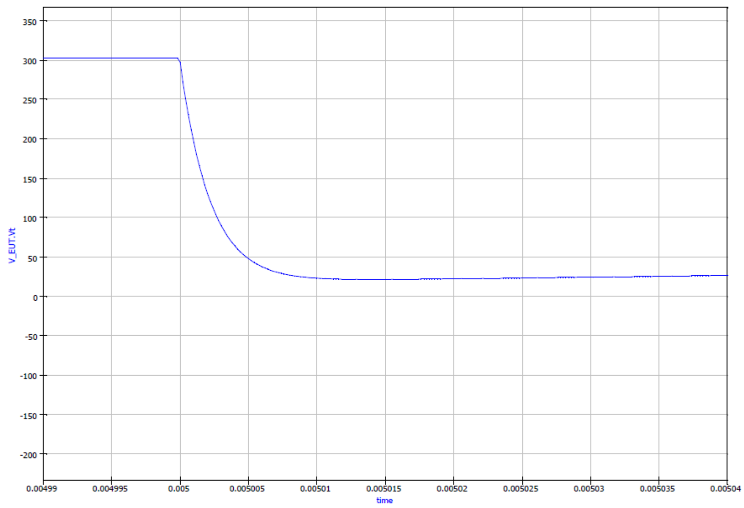

Fig. 4: Voltage characteristic during simulation (5µs/DIV)

PRACTICAL SHORT CIRCUIT MEASUREMENTS

To investigate the real occurring rise- and fall-times several practical measurements have been performed. The electrical installation of an existing building was provided. At two points of the installation a laboratory bench was set up. The installation of the building can be described with the following equivalent circuit diagram which was verified through a practical measurement of the installation of the building:

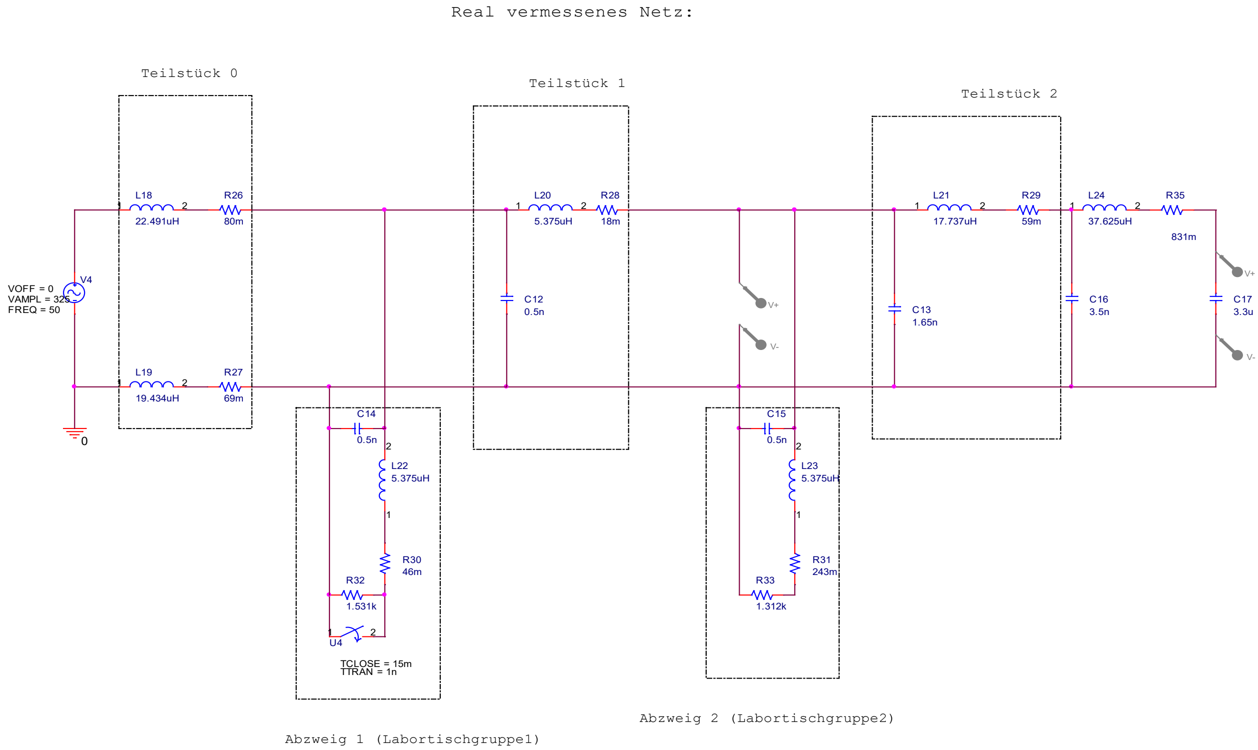

Fig. 5: Equivalent circuit of the building installation

The equivalent circuit shows three parts of the installation ("Teilstück 0-2") and the two workbench connections ("Abzweig 1/2"). The input voltage source is an ideal source with 230V nominal voltage at 50Hz. The parts "Teilstück 1", "Teilstück 2" and "Teilstück 3" are representing three parts of the current bar. The workbenches are connected with a supply cable with a length of 5m. Different EUT's were connected to the end of "Teilstück 2" with a supply cable of 35m length.

The inductive and capacitive parameters of the cabling system were determined using the technical report *„Simulation of short circuit on different places and influences on rise time"* of Mr.Lutz, *Fa. EMC Partner AG* as follows:

$$L_{line} := 1.075 \frac{\mu H}{m}$$

$$C_{line} := 0.75 \frac{\mu H}{m}$$

The serial impedances of the single cable parts were calculated through loading and measuring the voltage drop over the cable length.

<u>Practical measurement 1:</u>
Short circuit between L2 and N
without load
Measurement between
L2 and N

Voltage curve at point 1
fall-time approx. 200V/µs

Voltage curve at point 2
fall-time approx. 300V/µs

Voltage curve at the end of the line
fall-time approx. 300V/µs

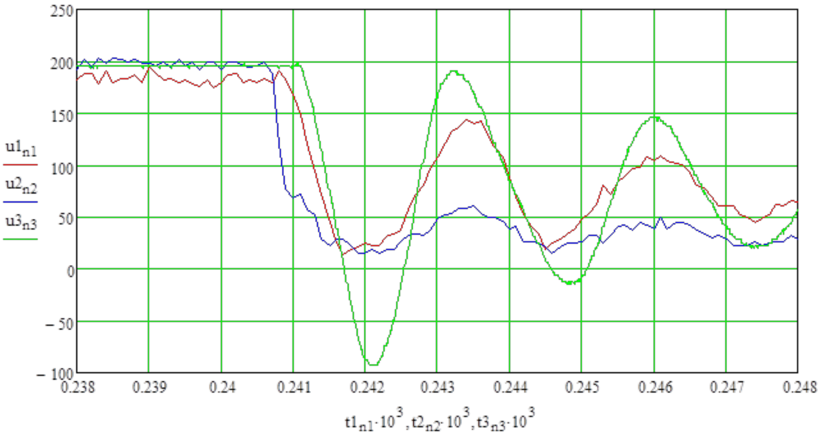

Fig. 6: Voltage curve at short circuit measurement 1 (5ms/DIV)

Detailed view:
Resolution 1µs/DIV

Voltage curve at point 2

Voltage curve at the end of the line

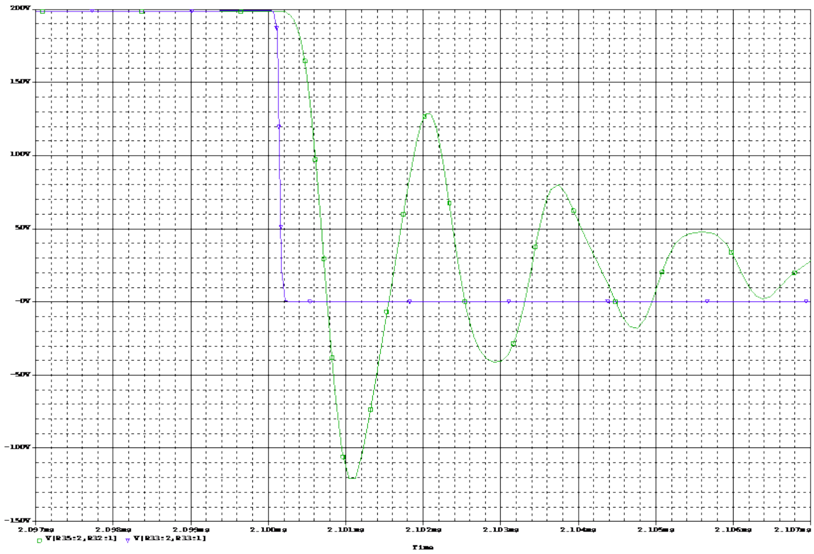

Fig. 7: Voltage curve at short circuit measurement 1 (1µs/DIV)

Detailed view:
Resolution 500µs/DIV

Voltage curve at point 2

Voltage curve at the end of the line

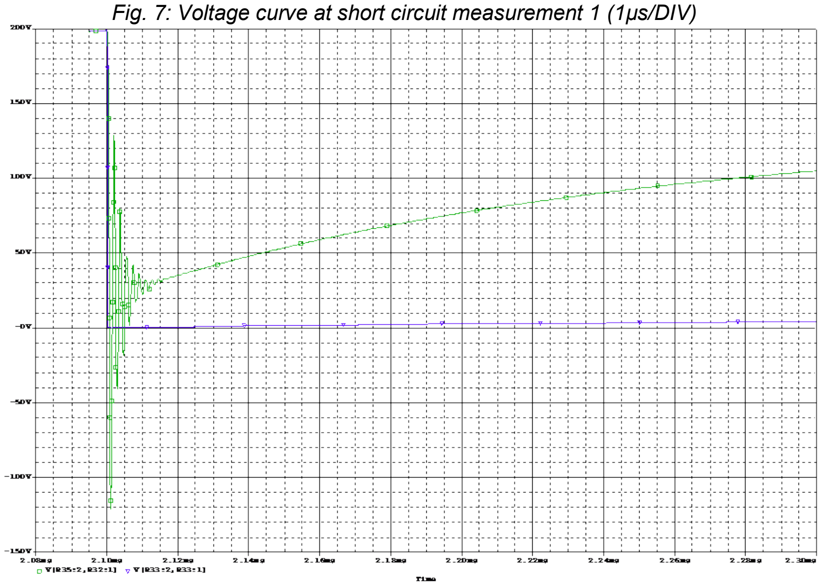

Fig. 8: Voltage curve at short circuit measurement 1 (500µs/DIV)

Practical measurement 2:
Short circuit between L2 and N with 600W rectifier load
Measurement between L2 and N

Voltage curve at point 1
fall-time approx. 300V/µs

Voltage curve at point 2
fall-time approx. 600V/µs

Voltage curve at the end of the line
fall-time approx. 350V/µs

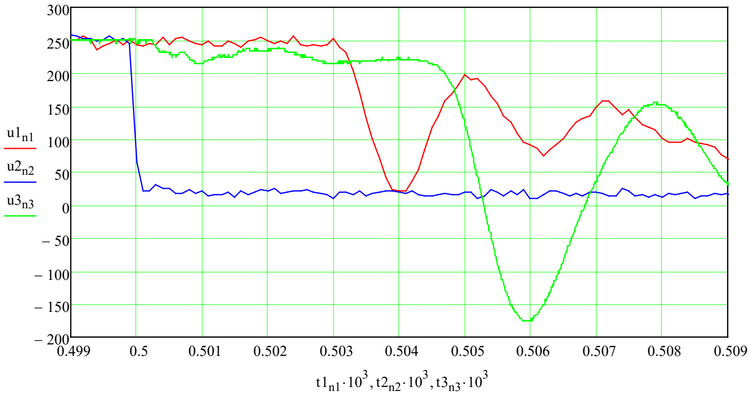

Fig. 9: Voltage curve at short circuit measurement 2 (5ms/DIV)

Practical measurement 3:

Short circuit between L2 and N
with 0,1uF//268Ω load
Measurement between
L2 and N

Voltage curve at point 1
fall-time approx. 300V/µs

Voltage curve at point 2
fall-time approx. 800V/µs

Voltage curve at the end of the line
fall-time approx. 65V/µs

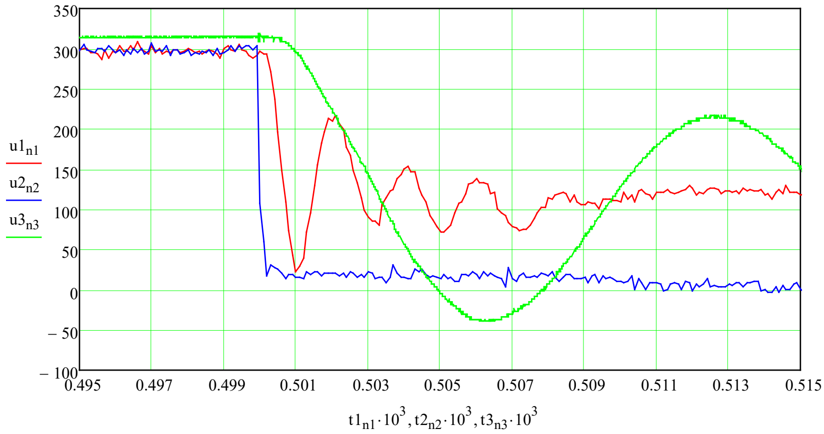

Fig. 10: Voltage curve at short circuit measurement 3 (5ms/DIV)

Detailed view:
Resolution 0,5µs/DIV

Voltage curve at point 2

Voltage curve at the end of the line

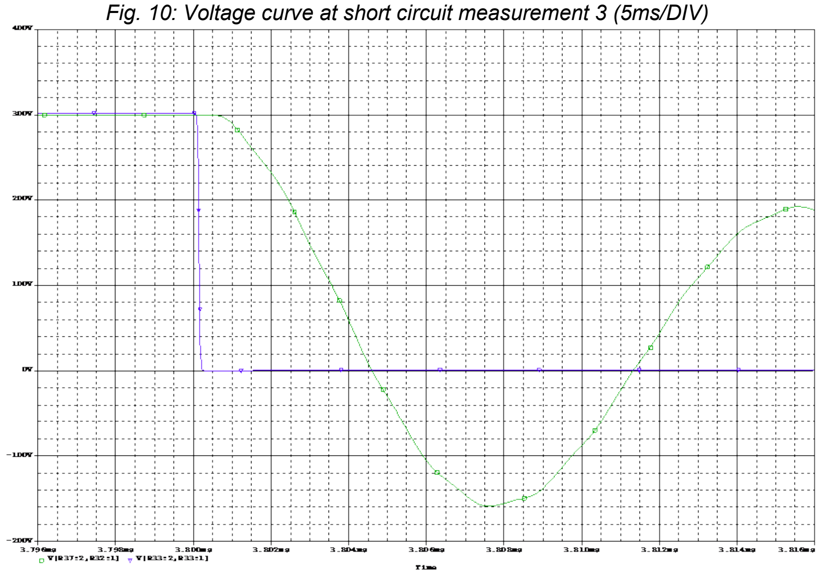

Fig. 11: Voltage curve at short circuit measurement 3 (0,5µs/DIV)

Detailed view:
Resolution 500µs/DIV

Voltage curve at point 2

Voltage curve at the end of the line

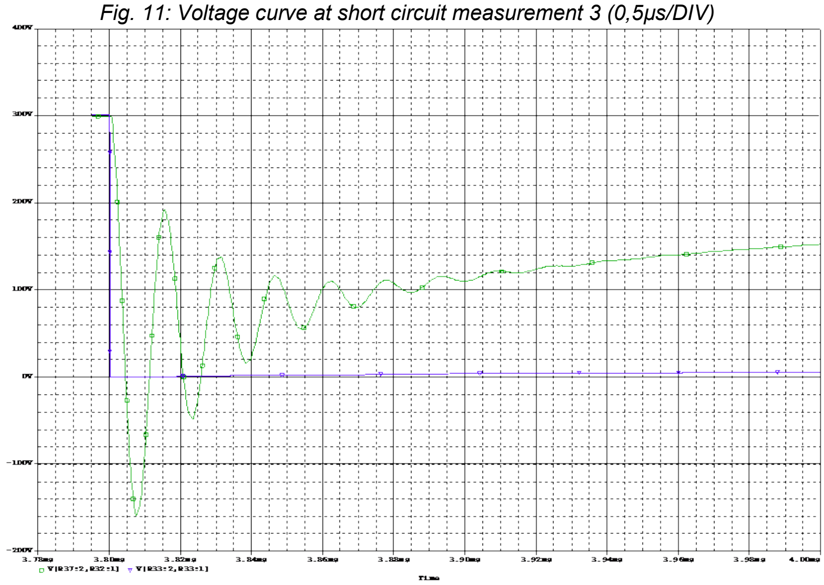

Fig. 12: Voltage curve at short circuit measurement 3 (500µs/DIV)

<u>Practical measurement 4:</u>

Short circuit between L2 and N with 1uF in series 16,5Ω load
Measurement between L2 and N

Voltage curve at point 2
fall-time approx. 2000V/µs

Voltage curve at the end of the line
fall-time approx. 40V/µs

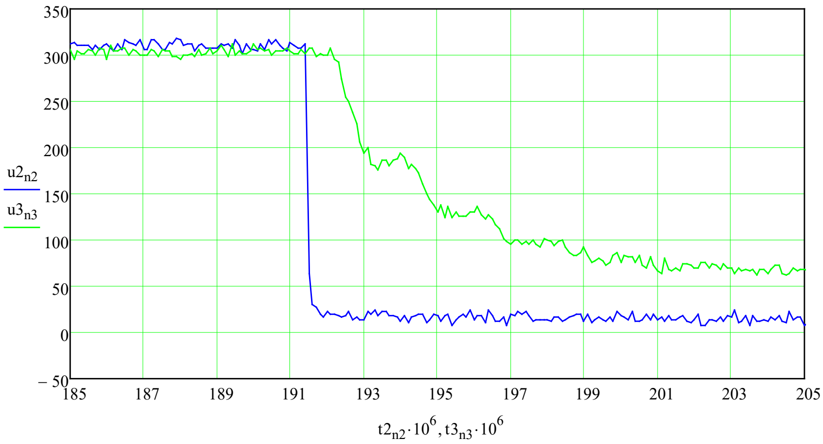

Fig. 13: Voltage curve at short circuit measurement 4 (5ms/DIV)

Detailed view:
Resolution 0,5µs/DIV

Voltage curve at point 2

Voltage curve at the end of the line

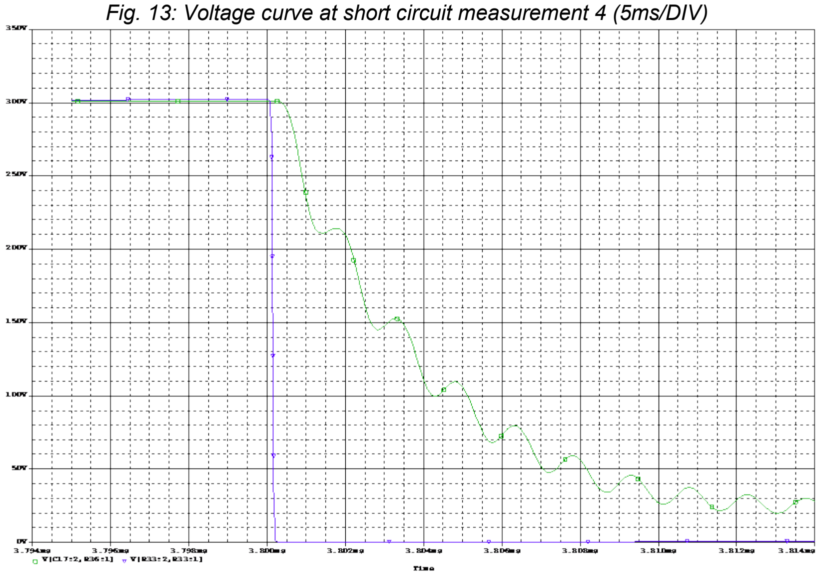

Fig. 14: Voltage curve at short circuit measurement 4 (0,5µs/DIV)

Detailed view:
Resolution 500µs/DIV

Voltage curve at point 2

Voltage curve at the end of the line

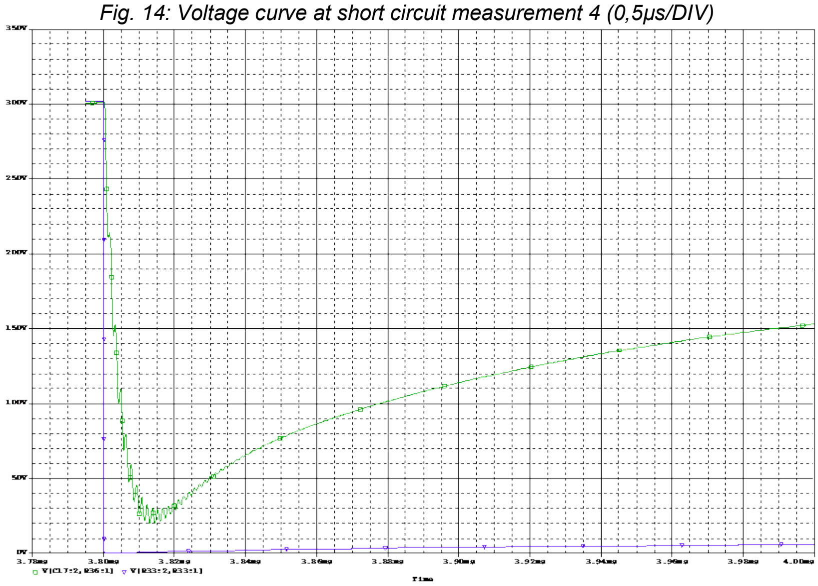

Fig. 15: Voltage curve at short circuit measurement 4 (500µs/DIV)

Practical measurement 5:

Short circuit between L2 and N
with 0,1uF in series 16,5Ω load
Measurement between
L2 and N

Voltage curve at point 2
fall-time approx. 2000V/µs

Voltage curve at the end of the line
fall-time approx. 40V/µs

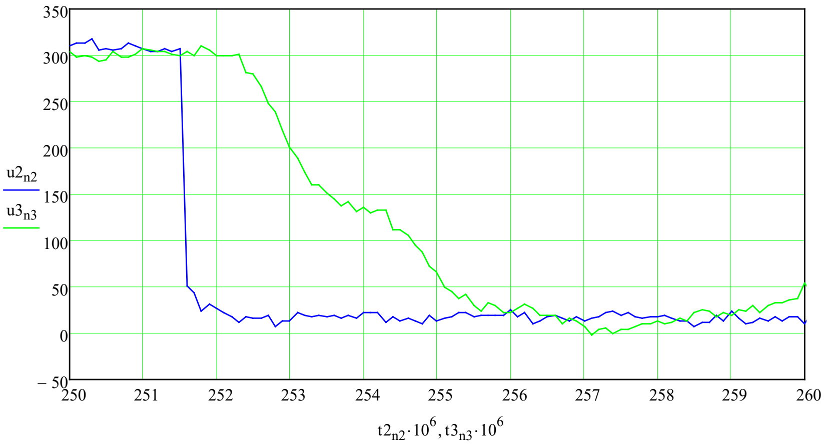

Fig. 16: Voltage curve at short circuit measurement 5 (5ms/DIV)

Detailed view:
Resolution 0,2µs/DIV

Voltage curve at point 2

Voltage curve at the end of the line

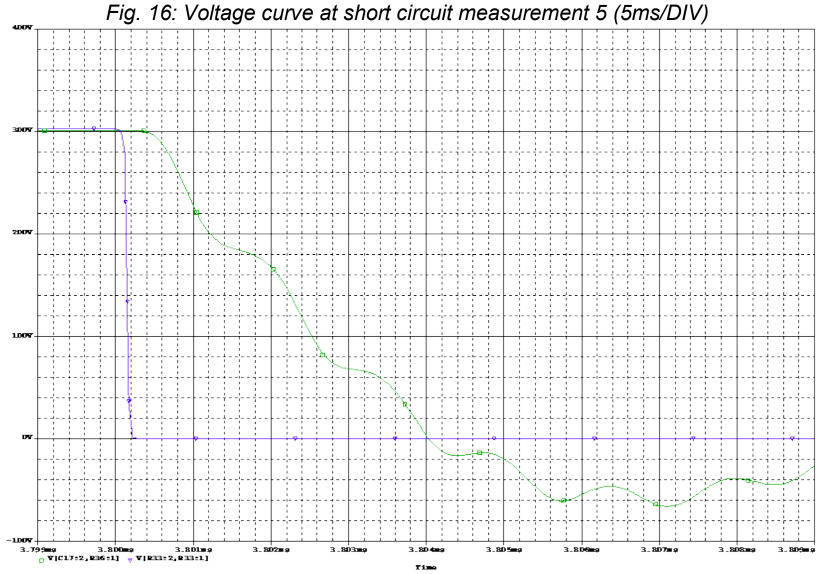

Fig. 17: Voltage curve at short circuit measurement 5 (0,2µs/DIV)

Detailed view:
Resolution 500µs/DIV

Voltage curve at point 2

Voltage curve at the end of the line

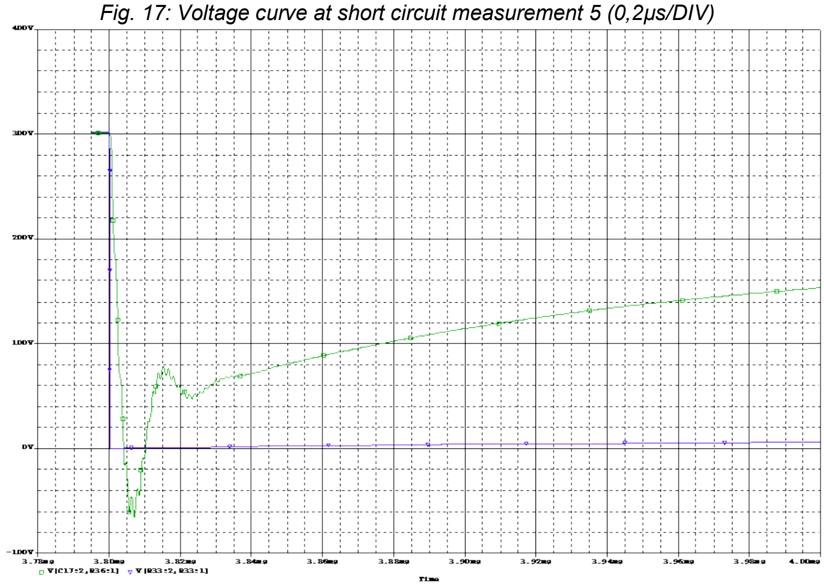

Fig. 18: Voltage curve at short circuit measurement 5 (500µs/DIV)

Practical measurement 6:
Short circuit between L2 and N
Measurement between
L1 and N

Voltage curve at point 1
fall-time approx. 10V/µs

Voltage curve at point 2
fall-time approx. 180V/µs

Voltage curve at the end of the line
fall-time approx. 15V/µs

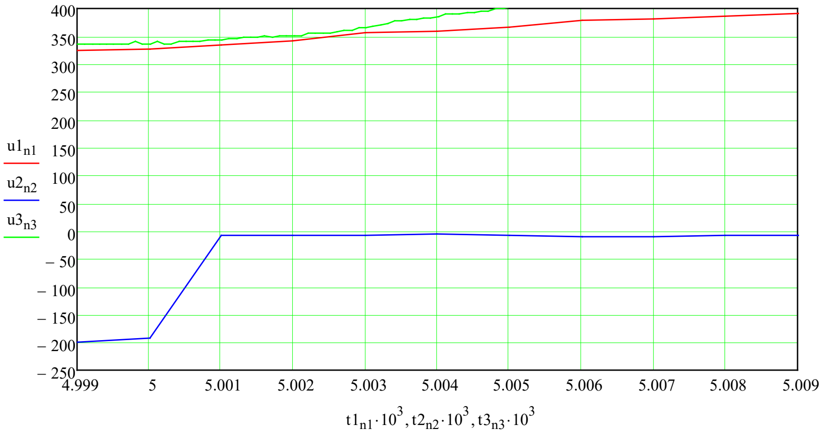

Fig. 19: Voltage curve at short circuit measurement 6 (5ms/DIV)

Practical measurement 7:
Short circuit between L1 and L2
with 0,1uF//268Ω load
Measurement between
L2 and N

Voltage curve at point 1
fall-time approx. 200V/µs

Voltage curve at point 2
fall-time approx. 300V/µs

Voltage curve at the end of the line
fall-time approx. 30V/µs

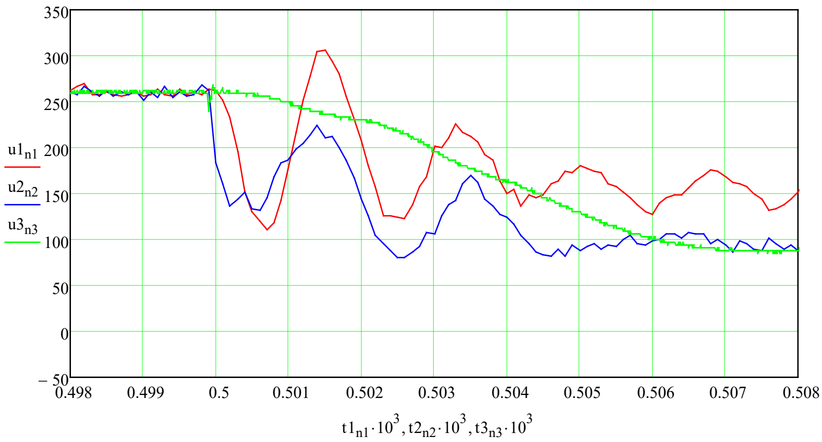

Fig. 20: Voltage curve at short circuit measurement 7 (5ms/DIV)

CONCLUSION:

These practical measurements are showing clearly:

1. The nearer the short-circuit appears, so much faster are rise- and fall-times.
2. Directly at the short circuit rise- and fall-times are faster than 1us.
3. Depending on the load and the distance to the short-circuit different rise- and fall-times can be measured, but all of them are between 1-5us.

In comparison between simulation and measurement data we can see, that simulation and reality are very close together.

„The definitions given in the IEC/EN 61000-4-11 of the preferred voltage source are very important to perform realistic test cycles.“