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Practical Exercise

Electromagnetic Compatibility

Exercise 7 High-energy single pulses (Surge) (Room L122a)

Group-Nr.: Minute taker:	Participant names:
Reviewed and approved by participants: (signed by all participants)	Stamp

Note: All questions need to be answered in advance! This practical exercise can only be performed when the answered questions are presented **before the start** of the experiment. In case of necessary corrections only the faulty pages should be replaced. The original faulty pages are added into the appendix and must be submitted too.

Introduction

Powerful transient pulses of different origin can be coupled into power supply and data cables. There are two types of pulses for consideration:

Pulses formed by switching events (SEMP – switching electromagnetic pulse):
E.g. by switching of capacitor banks, due to load changes in distribution networks, by resonant circuits (thyristors) or electrical shorts, so in general any fault that results in electric arcing in the grounding system of the mains installation.

Pulses formed by lightning (LEMP – lightning electromagnetic pulse):
Indirect lightning strikes, inside a single cloud, between clouds or in the vicinity of cables can create transient voltages/currents on mains lines outside or inside buildings.

In the High-Voltage-Lab of the Jade University these transient disturbances are created by a high energy wave (pulse) generator type Schaffner NSG 650. This test generator generates in open-circuit operation a voltage pulse with a front time of 1.2 µs and a voltage time to half value of 50 µs; in short-circuit operation a current front rise time of 8 µs, and a short-circuit current time to half value of 20 µs. This wave generator meets the requirements of the standard EN 61000-4-5.

The hybrid generator is able to provide a current pulse of (8/20) µs with a maximum current amplitude of 3.3 kA, in case the device under test (DUT) becomes low ohmic due to activated protective elements. Thus, a practical test can be ensured.
In this test, positive and negative pulses are applied to the DUT supply and signal lines by means of a coupling/decoupling network (CDN). The source impedance and the test level depend on:

- Line type (supply and signal lines)
- Cable length
- Coupling mode (symmetrical, asymmetrical)
- Installation of DUT

The internal resistance of the noise source is composed of the source impedance of the wave generator and a resistor inside the CDN. In detail, the following internal resistances are in place:

- 2 Ohm for symmetric coupling into supply lines (coupling capacitor C=18 µF)
- 12 Ohm for asymmetric coupling into supply lines (coupling capacitor C=9 µF)
- 42 Ohm for both coupling modes into signal and data lines.

The test levels are shown in Table 1 below with limits for power supply lines and signal lines:

Installation class	Test levels (kV)											
	AC power supply and a.c. I/O directly connected to the mains network Coupling mode		AC power supply and a.c. I/O not directly connected to the mains network Coupling mode		DC power supply and d.c. I/O directly connected thereto Coupling mode		Unsymmetrical operated [d,f] circuits/lines Coupling mode		Symmetrical operated [d,f] circuits/lines Coupling mode		Shielded I/O and communication lines [f] Coupling mode	
	Line-to-line	Line-to-ground	Line-to-line	Line-to-ground	Line-to-line	Line-to-ground	Line-to-line	Line-to-ground	Line-to-line	All lines-to-ground	Line-to-line	Line-to-ground
0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	0,5	NA	NA	NA	NA	NA	0,5	NA	0,5	NA	NA
2	0,5	1,0	NA	NA	NA	NA	0,5	1,0	NA	1,0	NA	0,5
3	1,0	2,0	1,0 [e]	2,0 [b,e]	1,0 [e]	2,0 [b,e]	1,0 [c]	2,0 [b,c]	NA	2,0 [b,c]	NA	2,0 [c]
4	2,0	4,0 [b]	2,0 [e]	4,0 [b,e]	2,0 [e]	4,0 [b,e]	2,0 [c]	4,0 [b,c]	NA	2,0 [b,c]	NA	4,0 [c]
5	[a]	[a]	2,0	4,0 [b]	2,0	4,0 [b]	2,0	4,0 [b]	NA	4,0 [b]	NA	4,0 [c]

[a] Depends on the class of the local power supply system.

[b] Normally tested with primary protection.

[c] The test level may be lowered by one level if the cable length is shorter or equal to 10 m.

[d] No test is advised at data connections intended for cables shorter than 10 m.

[e] If protection is specified upstream from the EUT, the test level should correspond to the protection level when the protection is not in place.

[f] High speed communications lines could be included under unsymmetrical, symmetrical, shielded I/O and/or communications lines.

Table 1 – Selection of the test levels (depending on the installation conditions)

As control unit for the wave generator, a personal computer is used instead of any switches on the front panel. The PC software provides a user interface with several functions. Among other things, freely programmable test sequences can be defined. All test sequences can be stored for repeated use, they can be logged in the report combined with the test parameters. The menu structure of the control program guides the user in a logical manner in the preparation of the test sequence. The program is started in DOS mode with the command „**NSG650**“.

Four separate test procedure can be configured:

- Single pulses
- Sequences with increasing test voltage
- Sequences with increasing phase angle
- Freely programmable combination of test sequences

For the coupling of the pulses into supply and data lines appropriate coupling networks (CDNs) are available.

Note: This equipment generates lethal high voltages. The safety regulations must be observed during operation. The operation must only be performed by qualified personnel.

Risk of fire and explosion by damaged DUT!

Circuit diagram and wave form

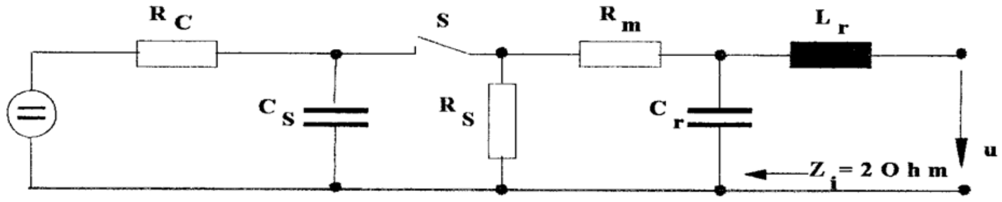

Figure 1 − Simplified circuit diagram of the wave generator

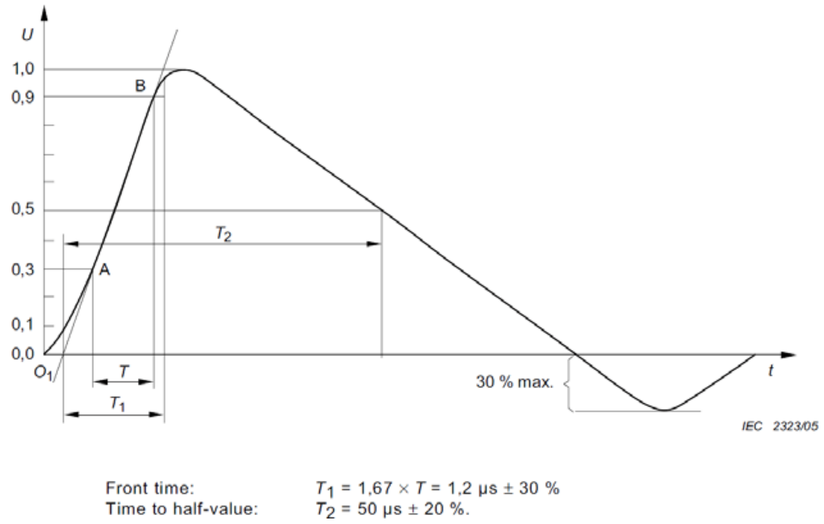

Figure 2 − Waveform of open-circuit voltage (1.2/50 µs) at the output of the generator with no CDN connected

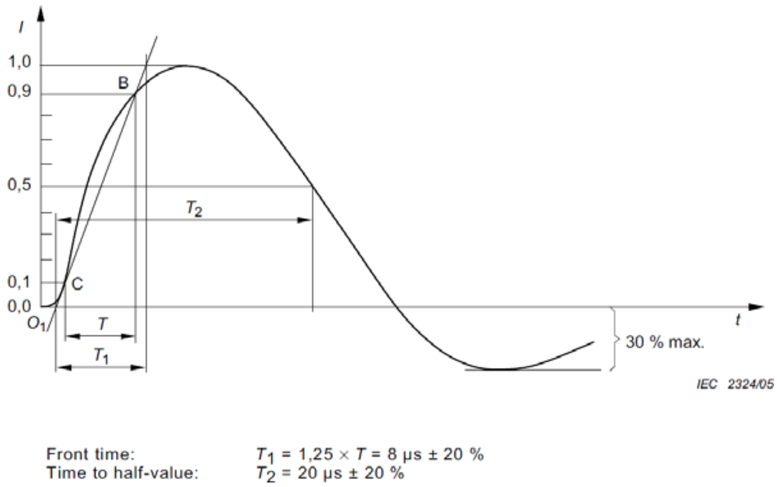

Figure 3 − Waveform of short-circuit current (8/20 µs) at the output of the generator with no CDN connected

Parameters for open-circuit and short-circuit condition:

$\hat{u}$ = (0.25 … 6.6) kV	$\hat{i}$ = (0.12 … 3.3) kA
T_1 = 1.2 µs	T_1 = 8 µs
T_2 = 50 µs	T_2 = 20 µs

(T_1 = front time; T_2 = time to half value)

Protection devices

Overvoltage arresters like gas discharge tubes (GDT), varistors or suppressor diodes are used as a graduated protection against the effects of surges. The characteristics of a protection circuit are given by operating voltage, discharge current capacity and response time.

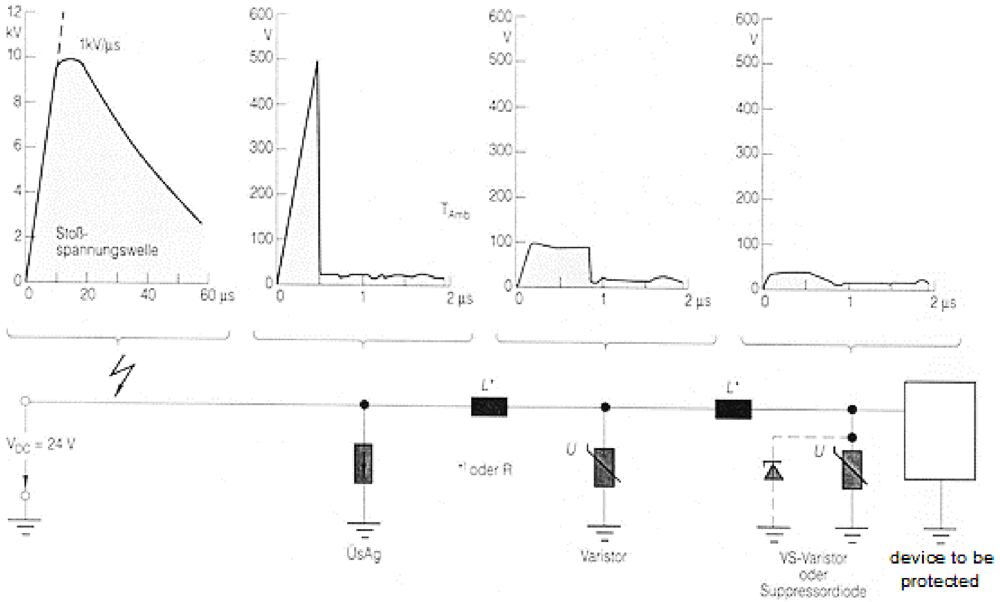

Figure 4 – Graduated protection with discharge tube, varistor or suppressor diode
(Note: The time scale shown for varistor and suppressor diode is faulty!)

Exercise

1.) Oscillograph the following signals using test voltages of 1 kV:

- Open-circuit output voltage of wave generator.
- Output current (short-circuit operation) with 2 Ω load (mode LZ).

2.) Record the time response of u = f(t) und i = f(t) as well as power dissipation p = f(t) over a varistor and a spark gap respectively (both in mode HZ).

3.) Oscillograph and explain the voltage response u(t) for the given graduated protection circuit for a 1 kV test voltage.

4.) Record the environmental conditions:
- Ambient temperature
- Rel. atmospheric humidity
- Atmospheric pressure

5.) Which environmental conditions are required according to the standard? It is necessary to review the most recent version of EN 61000-4-5 in order to find the correct answer (add a copy of the relevant page to the appendix of your report)!

→ The standard is available in the library of the Jade University (ask for assistance at info desk).

- Which page depicts the pulse shapes? What is the allowed tolerance?
- Which impedance is referred to in the description of the pulses?
- Do the measured pulse shapes comply with the standard?

6.) Select an appropriate varistor for the 230 V mains AC voltage. The varistor should withstand an 800 A current pulse (8/20 µs). Provide an explanation for your choice!
Add the respective varistor datasheet to your report and highlight the characteristic data relevant for your decision.
State the voltage drop over this specific varistor for 1 mA and 1 A current!

7.) Explain the terms „HEMP" and „NEMP"! Which standard is relevant for these terms?

8.) Explain the graduated protection scheme in general and in detail with respect to each of its components.

9.) Elucidate the test setup (as shown in EN 61000-4-5) for symmetric and asymmetric coupling into an AC mains network (add a sketch to your explanation)!

10.) Explain these terms:
„DC breakdown voltage and impulse breakdown voltage of surge arresters"!

11.) Prepare an overview and brief documentation of the equipment used!

Operating instructions:

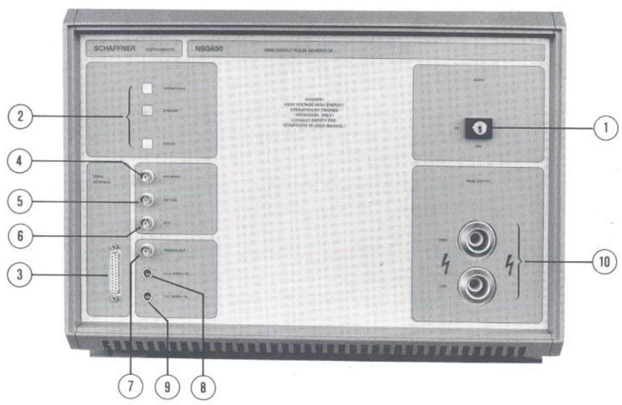

Figure 5 – Front panel of the wave generator

1 Safety key-operated switch
2 Status (operational / standby / error)
in case of error status check message on control PC
3 Serial interface for remote control
7 Trigger output for oscilloscope
8 U Monitor → pulse voltage monitor output
(floating output, 1:1000 attenuation, 5 % accuracy)
9 I Monitor → pulse current monitor output
(floating output, 1:1000 attenuation (1000 A ↔ 1 V), 5 % accuracy)

Wave generator and control PC are connected by optical fibre.
The control program "NSG650" will be started on the PC.

Denotations:

Surge LZ = Lightning pulse voltage with low dynamic impedance (2 Ω)

Surge HZ = Lightning pulse voltage with high dynamic impedance (12 Ω)

UP = Peak voltage of test pulse

Angle = Phase angle of voltage pulse relative to zero-crossing of mains AC voltage
Selection A or S:

- A = asynchronous, random pulse event
- S = synchronous to zero-crossing of mains AC voltage
  data input for definition of phase angle (0 … 359 deg)

"Space bar" is used to choose the respective control elements.
Testmode: Single (= single pulse)
Message: "Do you want to start the test" choose "YES" (by "space bar") → "CTRL-G" starts the actual impulse

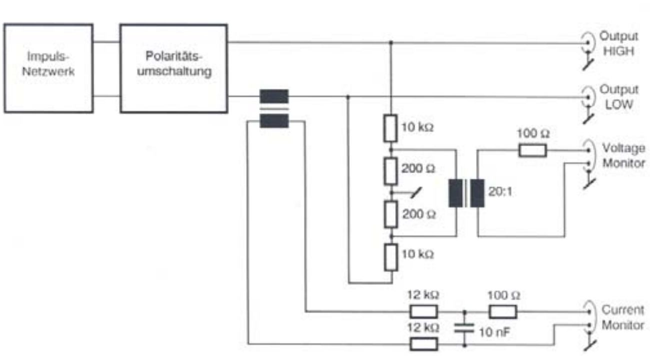

Figure 6 – Simplified schematic of monitor outputs

Measurement hints:

a) Open-circuit Surge HZ: time base 20 µs/Div voltage: 200 V/Div ; Trigger channel 1 (100 V)
b) Short-circuit Surge LZ: time base 5 µs/Div current: 100 A/Div Trigger channel 4, level: 3 V

Spark gap (GDT):

a) Overview setting:
Time base 0.5 µs/Div voltage: 200 V/Div current: 10 A/Div
b) Arcing voltage setting
Time base 20 µs/Div voltage: 10 V/Div current: 10 A/Div

Varistor: 200 V/div + 10 A/div with 20 µs/div

Graduated protection:
Time base 0.2 µs/Div all voltages: 100 V/Div