SURGE IMMUNITY OF ELECTRONIC EQUIPMENT

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Abstract

There was a tentative test of 20 video recorders at Darmstadt University of Technology with respect to the withstand capability against transient overvoltages. Transient overvoltages are a common phenomenon in low-voltage-installations. Most of these events originate from switching operations of other equipment or blowing of fuses. Depending on the location atmospheric events may contribute to the overvoltage stress.

The main goal of the test was to obtain information about the practical performance of consumer electronic equipment in normal use. Consequently the tests were performed taking into account the recent IEC-requirements with respect to electromagnetic compatibility (surge immunity [9]). The test levels were chosen according to the requirements with respect to insulation coordination (overvoltage category II [10]).

Only 7 of the sample with 20 video recorders passed the test without any failure. Almost all failures observed were located in the primary part of the power supply. Typically the radio interference suppression capacitors failed and/or internal fuses were blowing. Although the damage is rather small and limited to a few components, a rather expensive repair is required in any case.

Introduction

Failures in electronic equipment caused by transient overvoltages are increasing rapidly. The main failure mechanism and the origin of these overvoltages are not finally clarified until now. At the first glance atmospheric overvoltages seem to be the main source of such stress. But under normal conditions of exposure switching overvoltages are of higher relevance especially due to their frequent occurrence [1-4, 7]. The waveshape, amplitude and duration of transient overvoltages has a very high spread. This has to be compared with the high-voltage tests being applied at such equipment during type or routine testing.

In order to comply with product safety requirements usually a power frequency high-voltage test is performed [8]. The main purpose of such tests is the verification of protection against electric shock. Thereby the insulation of life parts against a conductive enclosure (basic and reinforced insulation) is tested. Functional insulation usually is not stressed by such tests. Additionally the test is performed without connection of the equipment to the mains supply and no functional requirements during or after testing apply.

In order to comply with the EMC-requirements besides other tests a high energy surge test is required [9]. This test also includes functional requirements and the equipment is energised during testing. Such tests can give more information about the practical performance of electronic equipment with respect to transient overvoltage stress. However the test levels, which are presently used for such tests, do not seem to be adequate to provide this information. An overview about these test levels and the corresponding open-circuit output voltage of the impulse test generator is given in table 1 [9].

Level	Open-circuit test voltage (±10%) kV
1	0,5
2	1,0
3	2,0
4	4,0

Table 1: EMC test levels (surge immunity) and open-circuit test voltages [9].

As the (open-circuit) output voltage of the impulse test generator is specified, the effective test voltage at the test specimen can be lower or significantly higher (resonance effects) than the specified value [5, 6]. This may influence the comparability of the results.

With respect to insulation coordination [11] and/or to provide protection against electric shock [10] impulse withstand voltages of low-voltage equipment according to table 2 apply depending upon the nominal voltage of the equipment.

Nominal voltage of the supply system V		Rated impulse voltage V Overvoltage category			
Three phase	Single phase	I	II	III	IV
	120-240	800	1500	2500	4000
230/400		1500	2500	4000	6000
400/690		2500	4000	6000	8000
Category I is for equipment for connection to accordingly protected circuits. Category II is for equipment to be connected to the fixed installation. Category III is for equipment within fixed installations (or for equipment with additional requirements). Category IV is for equipment at the origin of the installation.					

Table 2: Impulse withstand voltages for insulation co-ordination [11] and/or protection against electric shock [10].

According to table 2 usual electronic equipment to be connected to the 230 V low-voltage supply system (overvoltage category II) is required to have an impulse withstand voltage of 2,5 kV (at sea level).

Test conditions

This paper deals with the impulse withstand capability of video recorders being stressed with high energy impulses with a voltage waveshape (open-circuit) of 1,2/50 µs and a current waveshape (short-circuit) of 8/20 µs [9]. The tests were performed as described in IEC 61000-4-5 [9]. The test levels however were selected according to IEC 60364-4-443 [10] and IEC 60664-1 [11] respectively. For the test equipment IEC 61180 [12, 13] applies.

For testing a hybrid impulse generator with a virtual impedance of 2 Ω [9] was used. The tests of the class II equipment were performed between line and neutral. The equipment was energised in the stand-by mode. As overvoltages of 1,5 kV are occurring rather frequently, the tests were started just below this level. The test voltage was increased up to a maximum level of 3 kV, higher overvoltages must not be expected under normal conditions [1, 2, 7]. This maximum test level also complies with the relevant normative requirements [10-11].

The test voltage is the no-load output voltage of the impulse generator, however the applied voltage across the test specimen is being measured. All tests are performed for both polarities of the test voltage. The impulse was applied at the maximum of the positive or negative halfwave of the power frequency voltage depending on the polarity being used (worst case conditions).

Experimental set-up

Figure 1 shows schematically the experimental set-up for the impulse withstand test of the video recorders.

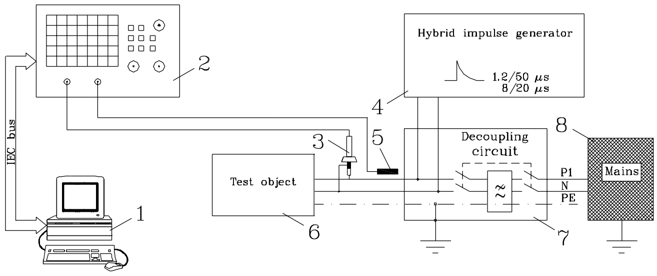

Figure 1: Experimental set-up for the impulse withstand test.

The output voltage of the hybrid impulse generator (4), is applied to the test object (6), which is connected to the low-voltage supply mains (8) by a decoupling circuit (7). Thus emission of the impulse voltage on the low-voltage supply mains is suppressed sufficiently. The voltage and current course is recorded directly at the test object by a digital oscilloscope (2), which is fed by a high-voltage probe (3) and a current transformer (5) respectively. The data are transferred from the oscilloscope to the PC (1) by the IEC-bus.

The hybrid impulse generator delivers standard impulses [12]. The waveshape of the open-circuit output voltage (1,2 µs ✎ 30 % and 50 µs ✎ 20 %) and the short-circuit output current (8 µs ✎ 20 % and 20 µs ✎ 20 %) were verified before testing. The results are shown in figures 2 and 3. Also the virtual impedance of the hybrid impulse generator is within the specified tolerance band of 2 Ω ± 15 %.

The observed ringing in the short-circuit current waveshape (Figure 3) is typical for such kind of impulse generators. The maximum amplitude of the polarity reversal is much less than the specified upper limit of 30 % [12].

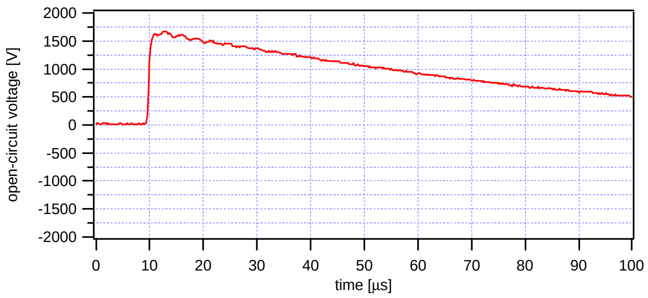

Figure 2: No-load output voltage of the hybrid impulse generator for a charging voltage of U_0 = 1500 V.

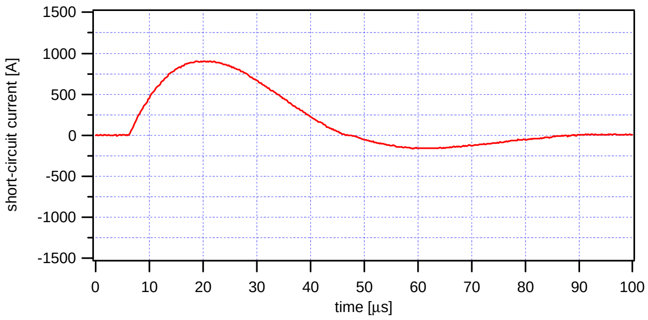

Figure 3: Short-circuit output current of the hybrid impulse generator for a charging voltage of U_0 = 1500 V.

Test results

The test results are summarised in table 3. The equipment are coded according to column 1. In column 2 the test voltage amplitude and its polarity (P, N), where the first significant failure occurred, is noted. In column 3 the status of the equipment after testing is evaluated. YES means no visible effect, (YES) means usually a defect in the radio interference suppression network, but the equipment is still functioning (probably not for a long period of time) and NO means a defect, where no function is possible any longer.

In most cases the mains fuses are mounted within the power supply beyond the metal screening. Therefore those are not accessible for the consumer and even for qualified personnel the replacement can be a problem (see figure 4, where the screen is soldered together with the main circuit board). As a replacement of a fuse is not possible for the consumer, such a failure leads to the statement NO in column 3 of table 3.

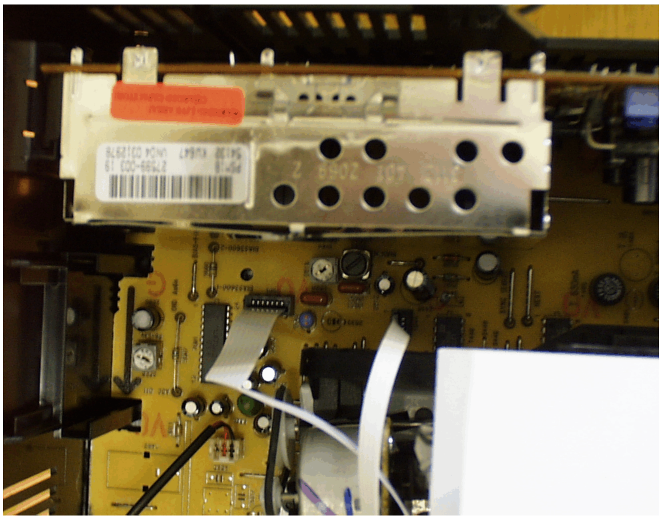

Figure 4: Inside view of a video-recorder (Code 02B).

Code	Voltage kV	Function after test	Comments
01B	3,0 N	(YES)	Radio interference suppression capacitor defect (non conducting)
02B	1,5 P	NO	Fuse defect; replacement impossible
03B	2,6 P	NO	Radio interference capacitor defect (partly conducting)
04B	3,0 N	(YES)	Radio interference suppression capacitor defect (non conducting)
05B	2,1 N	NO	Fuse and radio interference suppression capacitor defect
06B	—	YES	All tests up to 3 kV test voltage passed without effect
07B	2,6 N	NO	Fuse defect; replacement impossible
08B	—	YES	All tests up to 3 kV passed without effect
09B	2,7 N	NO	Fuse defect; replacement impossible
10B	—	YES	All tests up to 3 kV test voltage passed without effect
11B	—	YES	All tests up to 3 kV test voltage passed without effect
12B	3,0 P	(YES)	Radio interference suppression capacitor defect (non conducting)
13B	—	YES	All tests up to 3 kV test voltage passed without effect
14B	1,4 P	NO	Fuse defect; replacement impossible
15B	2,8 P	(YES)	Radio interference suppression capacitor defect (non conducting)
16B	—	YES	All tests up to 3 kV test voltage passed without effect
17B	3,0 N	NO	Radio interference suppression capacitor defect (conducting)
19B	2,4 P	(YES)	Radio interference suppression capacitor defect (non conducting)
20B	—	YES	All tests up to 3 kV test voltage passed without effect
21B	1,6 N	NO	Radio interference capacitor defect; at 2,4 kV (P) also fuse defect

Table 3: Summary of the test results.

According to table 3 only 7 of tested video recorders have passed the test. For 3 of the test specimen the test result was extremely poor, as failure already occurred at approximately 1,5 kV impulse voltage. In 1 case, due to the conductive radio interference suppression capacitor, also the risk of fire exists.
In most cases the X-capacitor has been damaged. Such damage, which is progressive after successive impulses, is likely to be the origin of the blowing fuses. Figure 5 shows a view into the input circuit of the power supply unit of a video recorder with damaged X-capacitor and defect fuse.

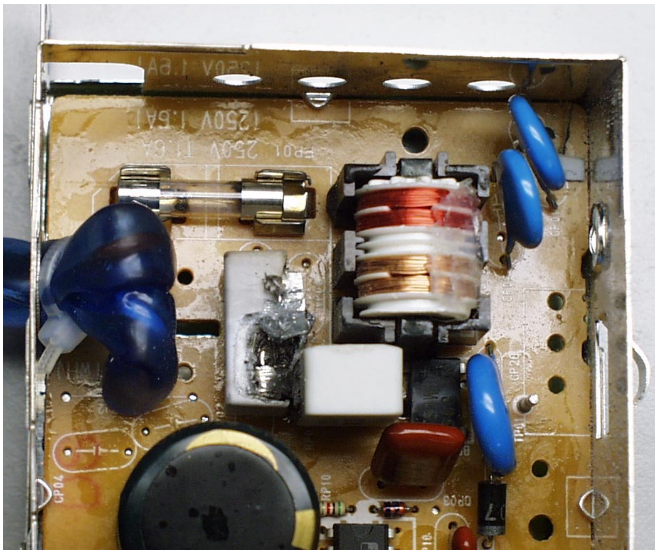

Figure 5: View into the input of the power supply unit with damaged X-capacitor and defect fuse (Code 03B).

Conclusions

Only 7 of the sample with 20 video recorders have passed the impulse test without any failure. Almost all failures observed were located in the primary part of the power supply. Typically the radio interference suppression capacitors failed and/or internal fuses were blowing. Although the damage is rather small and limited to a few components, a rather expensive repair is required in any case.

References

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