OVERVOLTAGE IMMUNITY OF ELECTRICAL APPLIANCES LABORATORY TEST RESULTS FROM 60 APPLIANCES

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ABSTRACT

During the last 20 years there has been verified a trend of more damage to electrical appliances in Norway. This increased level of damages has been believed to be caused by cheaper and poorer electrical appliances and increased numbers of appliances but also increased rms voltage levels and voltage swells to some customers in the low voltage network. The latter has partly been caused by stronger economic regulation of the Norwegian electric power network companies that has amongst others led to tougher utilization of the distribution network. Instead of strengthening the low voltage (LV) network with increasing load, many Distribution Network Operators (DNOs) tend to step up the transformer and introduce larger rms voltage variations from the transformer end to the far end of the low voltage network.

The paper describes new laboratory tests performed at SINTEF Energy Research during summer 2010 of 60 common electrical appliances' immunity to overvoltages and is an extension of similar test performed in 2008 [1]. These new tests go far beyond the previous test by increasing the maximum overvoltage duration from 100 seconds to 30 minutes and the maximum rms voltage from 320 V up to 400 V. Both the test procedure and the test results from the 60 appliances are presented in this paper. A surprisingly high percentage of the tested 230 V electrical appliances (Television sets, computers, computer screens, vacuum cleaners, music systems etc) handle quite severe overvoltages from +15 % up to +74 % (400 V rms) overvoltage with duration of 10 cycles up to 30 minutes.

INTRODUCTION

During the past 20 years there has been verified a significant trend of increase in damage to electrical and in particular electronic equipment in Norway. Repair workshops have often blamed overvoltages as the reason for the damage to for example the power transistor and other components in switch mode power supplies. When asking the manufacturer or national representative for a product about the overvoltage immunity of the product the answer is very often that they only guarantee that their equipment handle +10 % of the nominal rms voltage. Most manufacturers or national representatives are very reluctant to give information about what they expect the equipment can handle.

The observed trend can have several causes amongst others:

- Increased disturbance levels in LV distribution systems
- Reduced appliance immunity
- Reduced general quality in appliances by means of poorer component quality and reduced life time

Power Quality (PQ) measurements carried out in Norway by SINTEF Energy Research over the last 25 years show an increase in LV rms voltage drops from the feeding end to the far end in LV systems. It has also been observed an increase in average LV rms voltages. [2], [3]. One reason for this might be that the deregulation of the electricity sector in Norway has caused stronger utilization of the distribution network by many network companies as they have stronger incentives to postpone investments. When the load in LV systems has increased over years, the network has quite often not been strengthened. Many utilities have to a larger extent made tap changes to the distribution transformer to increase the rms voltage so that the customers at the end of LV circuits shall not get too low rms voltages during peak load hours. In this way the rms voltage at the customers closest to the transformer has been increased towards the +10 % level and in some cases above.

With rms supply voltages close to 230/400 V +10 % there are small margins for overvoltages (including swells) due to capacitor bank switching, other switching operations, load shedding etc. This situation has been thought to be some of the explanation to the increase in damaged electrical appliances.

Another explanation is a possible reduced immunity to rms voltage variations and disturbances in the electrical appliances or even a lower general quality of electrical appliances that causes a larger number to get damaged without significant voltage variations at all.

As a response to the described situation and with the objective to know more about the electrical appliances' immunity to voltage swells, a laboratory test [1] was performed in 2008 within the project “”A new concept for power quality and reliability measurement and management.” (PQM) [4] at SINTEF Energy Research. An extended follow-up test was performed in 2010 and the results form the latest test is reported in this paper.

PERFORMING LABORATORY TESTS

Due to good cooperation with one of the large Norwegian warehouses during the tests in 2008 it was also possible to get quite many appliances for a second test in 2010. All equipment that was returned to the warehouse from the customers due to visual defects caused by e.g. transportation and handling was made available for the project by the warehouse. These defects were typically scratches or dents to the cabinet/paint, scratches or cracks in the screen etc and had no influence to the electrical operation of the appliances. Also made available for the laboratory tests was equipment that was fully operational/working but which had been returned for recycling due to the simple reason that the owner had bought a new product. The tested electrical appliances therefore ranged from brand new equipment to quite old ones.

This way of obtaining the test objects for a test with possible damage to the test objects gave more freedom in presenting the test results than asking manufacturers or national representatives for a cooperation and willingness to supply electrical appliances for tests with possible damage to their electrical appliances.

The test was performed with several steps in duration and rms voltage and included significantly higher rms voltages and longer durations than the previous test in 2008. As in 2008, the rms voltage supplied to the test appliances always started and ended at 230 V rms. The rms overvoltage test area is shown in figure 1. An example of the test voltage wave shape is shown in figure 2 (100 ms with 400 V rms).

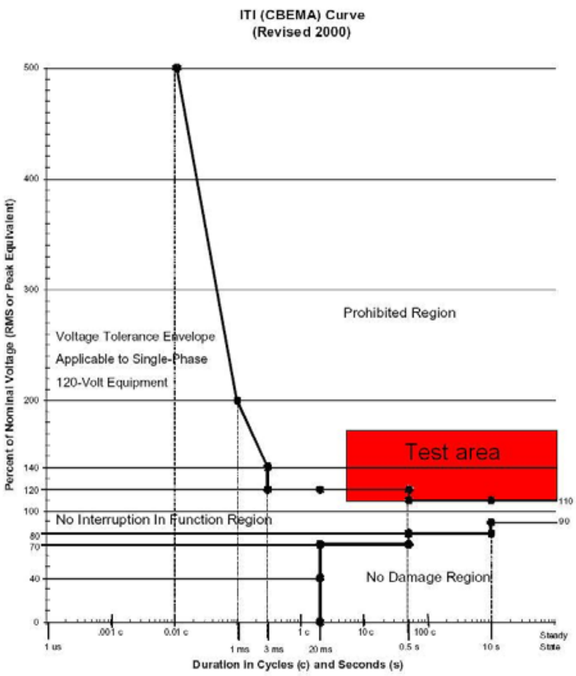

Figure 1: Overvoltage test area shown in the ITI curve.

The rms overvoltages used were: 230 V rms
+15 %, +20 %, +25 %, +30 %, +40 %, +52 % and +74 %.
(+12 % and +18 % used in 2008 was removed.)

The duration of the test rms overvoltages was:
100 ms, 1 s, 10 s, 60 s, 10 minutes and 30 minutes.
(100 s used in 2008 was removed.)

When the rms voltage was increased to the next test level the test was performed from shortest (100 ms) to longest (30 minutes) duration before the rms voltage was increased further to the next level.

Both the magnitude and the wave shape of the test voltage were measured with an Elspec G4420 instrument and the rms value was also monitored with a Fluke 87 true rms multimeter. The tested electrical appliances were turned on and set to a normal operational state before the test was performed. Stereo Hi-Fi systems were playing music, Televisions sets showing a picture and having sound in the speaker, etc. In addition to testing for possible damage to the equipment, the operational state of the equipment was also evaluated. If vacuum cleaners turn off or Television sets stop showing a normal picture on the screen etc, this is noted as a malfunction ("not working") due to the overvoltage.

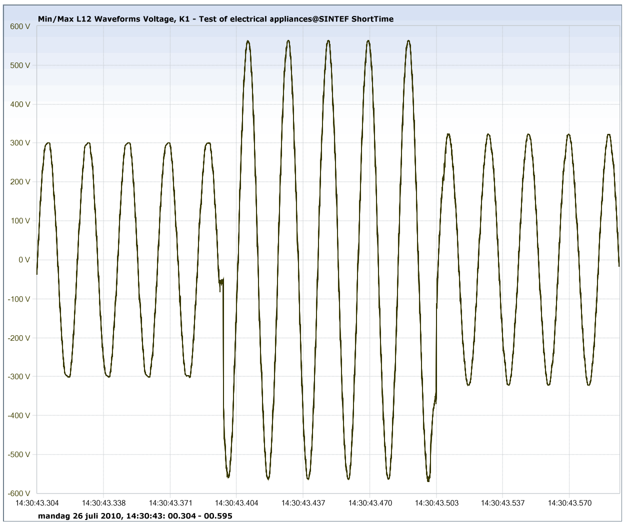

Figure 2: An example of the test voltage wave shape (100 ms with 400 V rms).

TEST RESULTS

The test results are summarised in table 1. When the tests at 230 V rms +20 % (276 V) was completed for all test durations including 30 minutes, only 1 of all the 60 tested electrical appliances was damaged. Additionally one DVD player and two vacuum cleaners did not work during the rms overvoltage but did work when the rms voltage dropped back from the increased value. Table 2 shows the colour code for table 1 results.

Table 1. Test results for the tested electrical appliances

Type of electric appliance	Overvoltage (rms) test level in % of 230V					
	115	120	125	130	140	152	174
CD player			10min				
circular saw	25min						
DVD player							1s
DVD player							0.1s
DVD player	20min	10s	25min				
home ent.system							1s
kitchen mixer							1s
microwave oven							10min
microwave oven						4min	3min
PC							1s
PC							2s
PC							1s
PC							0.1s
PC							1s
PC							0.1s
PC							50s
PC							
PC							0.1s
PC monitor							
PC monitor							10s
PC monitor							10s
printer							10s
printer							27min
printer							8s
printer							0.1s
printer							5min
printer							
printer							
printer							
radio					3min		
radio				10min			
radio					6min		
radio						20min	
radio					6min		
radio					10min		
stereo system						20min	
TV							10s
TV						30s	
TV						25min	
TV					0.1s	0.1s	0.1s
TV					0.1s	0.1s	0.1s
TV							
TV							0.1s
TV					0.1s	0.1s	0.1s
TV							0.1s
TV							1min
TV							20s
TV							0.1s
vacuum cleaner	15min	8min	6min	4min	3.5min	7.5min	0.1s
vacuum cleaner		8min	7min	6min	5min	3min	
vacuum cleaner							
vacuum cleaner							
vacuum cleaner						1.5min	
vacuum cleaner							
vacuum cleaner							
vacuum cleaner							
VHS player						20min	
VHS player							
VHS player							
VHS player						25min	

Table 2. Colour code for results. Time/duration to operation fail or damage is shown by numbers in the actual cell in the table.

	The electrical appliance is working during and after the test at this rms voltage level
	Not able to perform the test (amongst others due to too high load current for the rms overvoltage generator)
4min	Not working after 4 minutes at this rms voltage level but working when rms voltage is reduced
20s	The electrical appliance got damaged at this rms voltage level after 20 seconds

When the entire test up to and including 230 V rms + 74 % (400 V rms) was completed 42 of the 60 tested electrical appliances were damaged. Additionally 5 other appliances stopped working at various rms voltage levels but started working again when the rms voltage returned to the nominal voltage. 18 appliances were still working after the test was completed but 2 of these could not be tested at the highest rms voltages (at + 74 % for one appliance and both + 52 % and +74 % for the other) due to the appliances pulling a too large current for the test circuit at these rms voltage levels. Note that possible reduced life time expectancy of appliances surviving the test is not evaluated in these tests.

The accumulated number of damaged appliances with increased rms test voltage is shown in figure 3. The time when the equipment got damaged is shown in table 3.

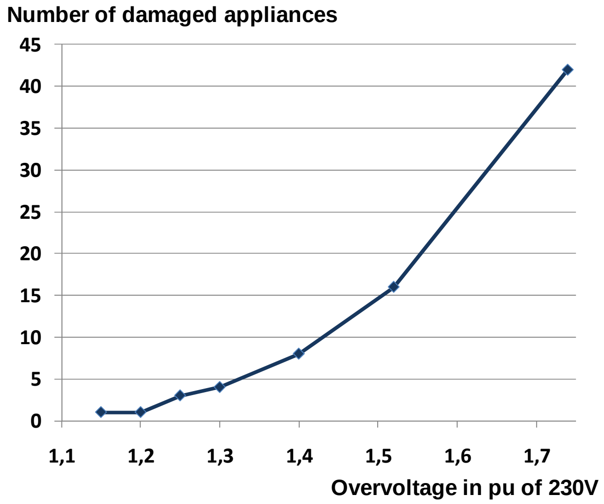

Figure 3: Number of damaged appliances (accumulated) with increased rms test voltage

Table 3. Time to damage. Number of damaged appliances in the different test time intervals.

Time	< 0,1 s	0,1-1 s	1-10 s	10-60 s	60 s-10 m	10-30 m	Total
Damaged	3	6	7	7	8	11	42

Result summary

- Overvoltages up to 322 V rms (U_N +40 %) with a duration up to 30 minutes results in damage of 13 % of the tested appliances.
- After the test was completed including 400 V rms in 30 minutes, 70 % of the appliances were damaged.
- 55 % of the damaged appliances are damaged within the first minute of testing at the rms voltage level causing damage.
- 45 % of the damaged appliances are damaged after a rms overvoltage duration between 1 minute and 30 minutes of testing at the rms voltage level causing damage.
- 27 % of the appliances survived the test and operated properly after the test was finished.
- 18 % of the appliances worked at 400 V rms for 30 minutes.
- Possible reduced life time expectancy is not evaluated in this test.

CONCLUSIONS

The two overvoltage tests in 2008 [1] and 2010 respectively indicate that electrical appliances in general have a quite high level of rms overvoltage immunity. A total of 122 appliances are tested (62 in 2008 and 60 in 2010).

During the latest tests (2010) only 1 out of 60 appliances was damaged after rms overvoltages up to U_N +20 % with duration up to 30 minutes. During the 2008 test only 1 out of 62 appliances was damaged after rms overvoltages up to U_N +20 % with duration up to 100 seconds. The results indicate a moderate percentage of damaged appliances as long as the rms voltage does not exceed U_N +20 %.

Even though a very high percentage of the tested electrical appliances do handle considerable increase in the rms voltage, at least for moderate durations the test also indicates that there are large variations between the different types (and models) of electrical appliances in terms of immunity to rms voltage swells. It must be expected that even with moderate rms overvoltages/voltage swells in the distribution system, a certain number of electrical appliances will get damaged.

It is however interesting to see that quite many appliances do handle rms overvoltages well even though they are considered low price to moderate price electrical appliances. The tests indicate that a fairly high level of rms overvoltage immunity might not be very costly to obtain in electronic equipment since the tested appliances mostly are moderate cost to low cost appliances.

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