An EMC Market Surveillance Project for Frequency Converters in Finland

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Abstract: Three EMC market surveillance projects have been carried out in Finland. The first project was for uninterruptible power systems, the second was for personal computers and the latest one has been for frequency converters. The project required the Finnish frequency converter market be monitored and manufacturers and importers identified. Much documentation was requested and thoroughly checked. Altogether 24 different frequency converter unit types were EMC tested.

In our particular project, only emissions were tested. We didn't consider immunity tests to be necessary since the requirements for immunity are easier to achieve. The manufacturer must, at any rate, ensure that the circuits of a frequency converter are immune to emissions made by the drive itself. In this paper, test results are given, analyzed and compared with results received from Sweden.

Market Surveillance in Europe

The free movement of goods and the removal of technical barriers to trade are key elements of the EU's single-market program and the European system with regard to conformity assessment. In a single European market, goods should be able to cross borders without re-inspection or retesting.

New EC Directives only set out essential requirements and legal aspects; this is known as the New Approach. Technical aspects are dealt with under specific standards which are voluntary in application. These standards are developed by specific bodies, such as CENELEC or ETSI, and are harmonized to meet the essential health and safety requirements of directives.

The functioning of the EU's single-market program depends on the vigilance of manufacturers in ensuring that products meet essential health and safety requirements, and on the product monitoring performed by national authorities once products are on the market. This monitoring, called market surveillance, is critical for maintaining consumer and business confidence within the present conformity assessment system.[1]

There are major differences between member states as to the way market surveillance is carried out. Some countries do not have a market surveillance organization while others carry out passive market surveillance, reacting only after crises occur. Some Member States, however, actively plan and execute the monitoring of product compliance. In order to make market surveillance effective, authorities must have the necessary authority and power to carry out their surveillance activities.

The European EMC Directive, 89/336/EEC, sets out the legal requirements on EMC for principally all electric and electronic equipment to be placed on the market or taken into use in The European Economic Area. European EMC requirements cover emissions as well as immunity.

EMC Market Surveillance in Finland

In Finland, responsibility for the market surveillance of the EMC Directive has been divided so that The Telecommunications Administration Centre (TAC) is responsible for telecommunications terminal equipment, other telecommunications equipment and radio equipment. Whereas, EMC surveillance for other electrical equipment comes under the responsibility of The Safety Technology Authority known as TUKES. TAC is also the authority for the new Directive 1999/5/EC on Radio equipment and Telecommunications Terminal Equipment. TUKES is, for example, the authority for the Low Voltage Directive, ATEX Directive and energy efficiency legislation.

For enforcing the New Approach Directives, TUKES has several tools available; notably field surveillance, document control and special projects. Surveillance is proactive which

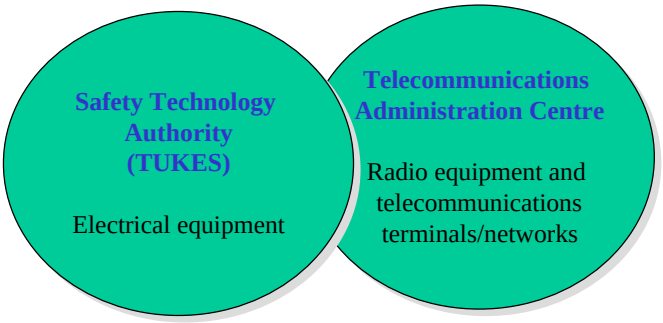


Figure 1. Responsibilities for EMC market surveillance in Finland

requires that TUKES's field inspectors regularly visit commercial outlets through which products are sold. They carry out visual inspections of products available. If any prove to be questionable with regard to the conformity of any product, TUKES's inspectors have the authority to purchase units with a view to forwarding them on for testing at a competent testing laboratory. [2]

In 1994, the advance approval system for electric equipment ended in Finland and the market surveillance system commenced. TUKES's inspectors have, from the beginning of the new system until the present day, carried out about 18 400 surveillance visits to outlets, importers and manufacturers. Inspectors have purchased about 6 300 products which have been tested at competent laboratories.

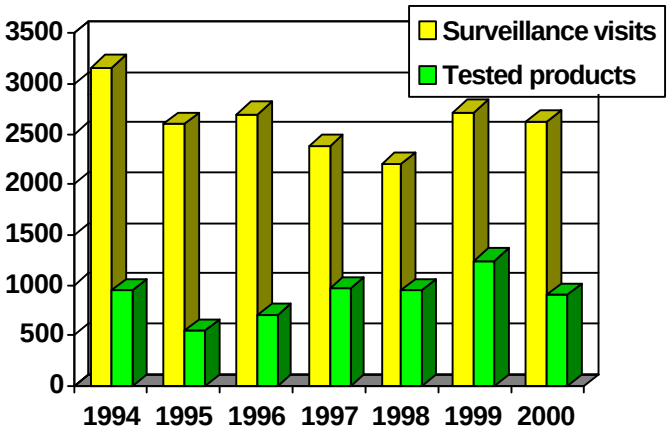


Figure 2. Surveillance visits and safety tested products 1994 - 2000

Most of these tests have been safety tests but the EMC properties of every product have, at least, been visually checked with EMC requirements in mind. If any signs of failure with regards to EMC have been identified, such as the lack of an RF filter in some product, then EMC tests have been made.

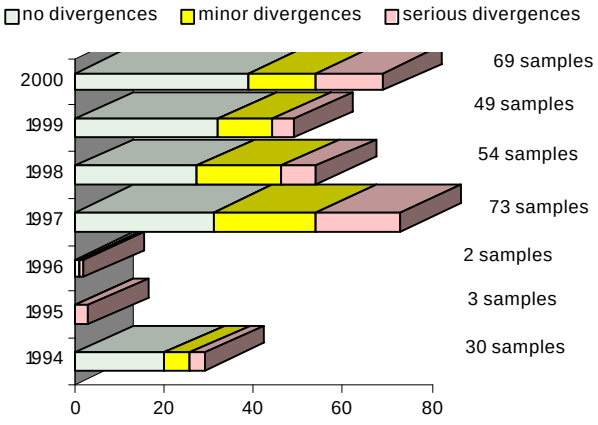


Figure 3. EMC market surveillance tests

Fig. 3 shows how many samples have been actually EMC tested each year, from 1994 to 2000, and what the results have been. In each year following 1997, about 53 % of the tested samples have been satisfactory and have fulfilled the requirements of EMC standards. About 27 % have had minor divergence and 20 % serious ones. However, there were great differences by equipment group, as shown in Fig.4. Equipment used in information technology is clearly the most problematic group, the second being power electronics.

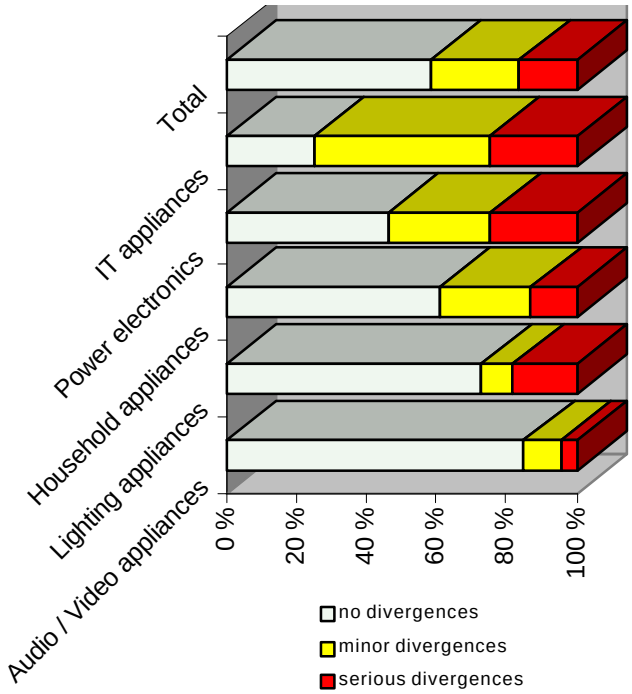


Figure 4. Results of EMC tests by equipment group

EMC market surveillance projects

What is the purpose of EMC market surveillance projects? There are two main reasons for having them: First, it is known that some products cause more EMC problems than others. And, by using a project, resources can be better allocated. The second reason is that project results are normally easy to publish and so market surveillance gets more visibility and a higher profile. Both of these help EMC market surveillance because when the subject of surveillance realizes that he/she is under scrutiny, he/she maintains his/her own quality monitoring more carefully.

To date TUKES has had three EMC market surveillance projects. The first was for uninterruptible power systems, results can be seen in [3] and [4]. The second was for personal computers, results are as in [5]. The third considered frequency converters. Now we are going ahead with energy saving lamps.

The frequency converter project

A frequency converter is an electronic power unit which provides the adjustable control of the speed of AC motors by converting fixed mains voltage and frequency into variable quantities. Today's frequency converters are microprocessor-controlled digital units.

Energy saving is the main advantage gained when controlling motors with frequency converters. Since frequency converters have become compact, competitively priced and versatile, they have become more commonly found. Motors driven by frequency converters can be found in pumps, ventilators, conveyor belts, lifts, air conditioning and also in the automation systems of industrial installations.

A typical interference situation is when a radio amateur has a roof antenna near the engine room of a lift and its frequency converter causes disturbances. Also, the same type of interference can come from an air conditioning system.

Our project required the Finnish frequency converter market be monitored and manufacturers and importers identified. A significant amount of documentation was requested and thoroughly checked. Altogether, 24 different frequency converter unit types were EMC tested.

In our particular project, only emissions were tested. We didn't consider expensive immunity tests to be necessary since the requirements for immunity are easier to achieve. A manufacturer must, at any rate, ensure that the circuits of a frequency converter are immune to emissions made by the drive itself. Also, all complaints concerning frequency converters have related to emissions. Swedish immunity test results concerning frequency converters and our own immunity test results from UPSs [3], [4], support the approach that immunity aspects are not a real problem for power electronic equipment on market.

Tests on Frequency Converters Performed in Finland

EMC market surveillance tests performed on frequency converters in Finland, were performed in accordance with the standards EN 55011:1991 "Industrial, scientific and medical (ISM) radio-frequency equipment" or EN 55022:1994 "Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement", depending on a manufacturer's EC-Declaration of conformity. In these standards the equipment is classified under two categories: *Class A* and *Class B. Class B* equipment is suitable for use in all establishments whereas *Class A* equipment is suitable for use in all establishments other than domestic ones.

The tests were made by SGS FIMKO Ltd. and EMCEC Ltd. which are accredited EMC testing laboratories with Competent Body status in accordance with the rules of European Commission.
A summary of tests:

- Measurement of mains terminal interference voltage within the frequency range 0.150 -30 MHz
- Measurement of radiated interference field strength within the frequency range 30 - 1000 MHz
- The equipment under test (EUT) was set for the normal mode operation, the motor was running with no load at nominal speed and voltage.
- The output frequency was set to 35 Hz.

The first tests were performed inside a shielded room at a measurement distance of 3 meters. In many cases, not all accessories were sold with the frequency converter which had been mentioned in the equipment installation instructions. In this first testing period, test connections were made only with accessories which were retailed with equipment. In this way, we discovered the EMC ability of the equipment in a situation in which extra accessories had not been obtained and which is felt to be the most realistic installation set-up.

Results

A summary of testing results at a measurement distance of 3 meters is given in Table I. The labeling "P" in Table I means that the Equipment Under Test (EUT) fulfils requirements. The numerical values show how much, and at which frequency, limits were overrun by. Values are quasi-peak (QP) values.

Only 10 frequency converters out of 24 passed the 3 m tests. There were serious defects found in 8 units (excess more than 10 dB above the limits of the test standard). Minor defects (excess less than 10 dB) were discovered in 6 units.

Test connections in 3 m tests were made with accessories delivered with the unit. In many cases, there were no accessories or the wrong accessories were delivered with the unit. However, the missing accessories were generally mentioned in installation instructions.

Six frequency converters with serious defects were re-tested inside a shielded room at a measurement distance of 10 meters (Table II). In this second test period, EUT was installed using all the accessories mentioned in the operating instructions.

Two converters with serious defects (num. 18 & 19) were not re-tested by us. The importer had made mistakes with the housing of these models. These mistakes were clear to identify. Soon after, the importer and manufacturer organized re-testing and mistakes were consequently rectified. Re-tests were performed in Germany by Phonenix Test Lab, which also has competent body status. Units 18 & 19 passed the re-test.

Market Surveillance Tests Performed in Sweden

Frequency converters have been tested in Sweden too. In year 2000, the Swedish Authority sent TUKES the test results on 20 frequency converters. So we were then able to compare our results. Units had been tested for the previous 4 years. In 1996 and in one specific case, in 1999, both emission and immunity tests were made. Problems with immunity were only found in a single case. According to test results there were defects found in 17 units out of 20.

Table 1. Tested frequency converters and summary of results. Measuring distance 3 meters.

Description of Equipment			Emission tests [1]		
Number	Nominal Voltage	Country of manufacturer	Mains terminal interference voltage [2]	Radiated interference field strength [2]	Test Standard, Class
1	3×400 V	Finland	P	P	EN 55011 cl. A
2	1×230 V	Finland	P	P	EN 55011 cl. A
3	3×400 V	Germany	P	+30.10dB at 37.15MHz	EN 55022 cl. B
4	1×230 V	Germany	P	+14.34dB at 40.16MHz	EN 55011 cl. A
5	1×230 V	?	+42.35dB at 0.26MHz	+20.2dB at 34.84MHz	EN 55022 cl. B
6	1×230 V	Germany	+1.77dB at 4.40Mhz	+13,05dB at 220MHz	EN 55011 cl. B
7	3×400 V	?	P	P	EN 55011 cl. A
8	1×230 V	?	+6.72dB at 4.98MHz	P	EN 55022 cl. B
9	3×400 V	Austria	+7.60dB at 9.40 MHz	P	EN 55011 cl. A
10	3×400 V	Germany	+17.68dB at 0.15MHz	+7.66dB at 39.99MHz	EN 55022 cl. B
11	3×400 V	UK	+4.84dB at 11.84MHz	+19.09dB at 46.40MHz	EN 55022 cl. B
12	1×230 V	?	+6.24dB at 9.23MHz	+8.52dB at 41.0MHz	EN 55022 cl. B
13	3×400 V	Japan	P	P	EN 55011 cl. A
14	1×230 V	Japan	P	+3.82dB at 41.10MHz	EN 55011 cl. A
15	3×400 V	Finland	P	P	EN 55022 cl. B
16	3×400 V	Singapore	2.84dB at 0.15MHz	P	EN 55011 cl. A
17	1×230 V	Singapore	P	P	EN 55011 cl. A
18	3×400 V	Japan	+6.23dB at 8.00MHz	+28.27dB at 43.70MHz	EN 55011 cl. B
19	1×230 V	Japan	P	+17.51dB at 35.76MHz	EN 55011 cl. B
20	3×400 V	Denmark	P	P	EN 55011 cl. A
21	1×230 V	Denmark	P	P	EN 55011 cl. A
22	3×400 V	Japan	P	P	EN 55011 cl. A
23	1×230 V	Japan	P	P	EN 55011 cl. A
24	3×400 V	UK	P	+3.22dB at 34.58MHz	EN 55011 cl. A

[1] Numerical values mean how much measured quasi-peak values were above the limits of test standard. ”P” means that the EUT passed test.

[2] Measurement uncertainty is below ±3.9dB with a confidence of 95%.

Table 2. Retested frequency converters and summary of results. Measuring distance 10 meters.

Description of Equipment			Emission tests [1]		
Number	Nominal Voltage	Country of manufacturer	Mains terminal interference voltage [2]	Radiated interference field strength [2]	Test Standard, Class
3	3×400 V	Germany	-	+6.3dB at 83.84MHz	EN 55022 cl. B
4	1×230 V	Germany	-	+1.4dB at 64.60MHz	EN 55011 cl. A
5	1×230 V	?	+20.30dB at 6.20MHz	+19.8dB at 52.00MHz	EN 55022 cl. B
6	1×230 V	Germany	-	+21.0dB at 40.00MHz	EN 55011 cl. B
10	3×400 V	Germany	P	-	EN 55022 cl. B
11	3×400 V	UK	-	+12.80dB at 30.08MHz	EN 55022 cl. B

[1] Numerical values mean how much measured quasi-peak values were above the limits of test standard. ”P” means that the EUT passed test.

[2] Measurement uncertainty is below +3.1dB/-4.0dB with a confidence of 95%.

Table 3. Tests Performed in Sweden.

Description of Equipment			Emission tests [1)]		
Number	Nominal Voltage	Country of manufacturer	Mains terminal interference voltage	Radiated interference field strength	Test Standard, Class
1	3×400 V	Denmark	+4dB at 0.157 MHz	P	EN 55011 cl. A
2	3×400 V	USA	+2dB at 5.771 MHz	+25dB at 51.634 MHz	EN 55011 cl. A
3	3×400 V	Japan	+17dB at 0.662 MHz	+32dB at 53.019 MHz	EN 55022 cl. B
4	3×400 V	Finland	+43dB at 0.150 MHz	+6dB at 79.218 MHz	EN 55011 cl. B
5	3×400 V	France	P	P	EN 55022 cl. A
6	3×400 V	Sweden	+34dB at 0.150 MHz	+6dB at 51.316 MHz	EN 55011 cl. B
7	1×230 V	?	-	+1dB at 37.543 MHz	EN 55022 cl. A
8	3×400 V	UK	-	+14dB at 30.523 MHz	EN 55022 cl B
9	3×400 V	UK	+11dB at 0.640 MHz	P	EN 55011 cl A
10	3×400 V	UK	+7dB at 1.141 MHz	+17dB at 72.062 MHz	EN 55022 cl B
11	3×400 V	Sweden	+13dB at 0.717 MHz	+4dB at 46.630 MHz	EN 55011 cl B
12	1×230 V	Japan	+34dB at 0.157 MHz	P	EN 55011 cl A
13	1×230 V	Canada	Immunity 1,88-2,02 MHz		ENV 50141
14	1×230 V	Canada	P	P	EN 55011 cl A
15	1×230 V	Japan	P	P	EN 55022 cl B
16	3×400 V	Sweden	P	+10dB at 180 MHz	EN 55011 cl A
17	3×400 V	UK	P	+11dB at 228 MHz	EN 55022 cl B
18	1×230 V	Germany	P	+8 dB at 37.45 MHz	EN 55011 cl A
19	1×230 V	Taiwan	P	+11 dB at 44.56MHz	EN 55022 cl B
20	1×230 V	Sweden	AV 3dB at 0.187 MHz	P	EN 55011 cl A

1) Numerical values mean how much measured quasi-peak values were above the limits of test standard . ”P” means that the EUT passed test.

The Swedish test strategy was to make the test set-up as near to reality as possible, which means that the test set-up was not necessarily according to the provisions set up in a harmonised standard. The test set up therefore followed the manufacturers installation instructions in detail since, in the installation instructions the manufacturer has the opportunity to make necessary restrictions or demands for special measures so as to ensure that the installation fulfills the EMC-requirements. In Sweden, they concluded that the main reason for bad results was the unclear instructions given for installation. They also recommended that manufacturers amended instructions.

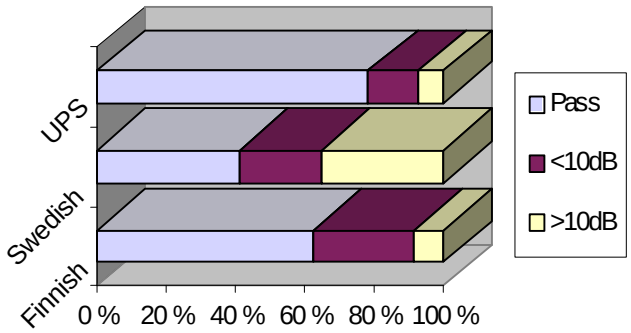
The Analysis of Results

Typical disturbances caused by a frequency converter are due to incorrect design and installation. Such problems can be avoided when both the converter and the system utilizing it comply with the requirements of the EMC Directive. In the design and planning, attention must be paid to the installation method and placing. Earthing, protection and filtering are also critically important.

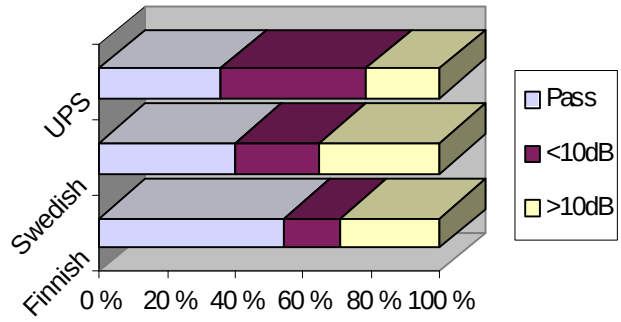
The first tests were carried out using the installation accessories supplied with devices. During the tests, the emission of disturbances in as many as 14 converters exceeded the threshold values of the testing standard. Eight models measured consistently in excess of threshold values. Test results proved that the use of a frequency converter does not automatically comply with the requirements, if the installation instructions are not followed at installation and if correct installation accessories are not used. A re-test was carried out on six models, in which most of them still exceeded threshold values.

A comparison between Swedish and Finnish frequency converter test results and Finnish UPS test results is made in Fig. 5. Results shown in Fig.5 prove that emission problems are generally significant in power electronic devices. When comparing Swedish and Finnish frequency converter results, it can be seen that there were more defects (<10 dB) and serious defects (>10 dB) in Sweden. Also Finnish UPS test results are worse than Finnish frequency converter results. The UPS project was performed in 1997 and converters were tested in Sweden during 1996-1999. Obviously the EMC properties of power electronics have advanced in four years. According to these results, radiated emission is the most common defect in power electronics, even though conducted mains terminal interferences are general, too.

According to Swedish results, immunity is a much smaller problem than emissions for frequency converters. Our UPS test results support that conclusion in all power electronic equipment.



a) Mains terminal interference voltage



b) Radiated interference field strength

Figure 5. Comparison of results

Sanctions

Three retested models exceeded threshold values considerably. It was decided to place a sales ban on them. For minor defects, we gave admonishments to importers and manufacturers regarding nine products. We recommended manufacturers should note our test results and develop their products with a view to achieving better compliance with harmonized standards.

In Sweden three of the tested converters ware banned from the market. With regard to the remaining converters that did not pass the test, the Swedish Authority started a dialog with the manufacturers in order to acquaint them with the problems. In general, the bad results were due to unclear or missing instructions in the installation manuals. In these cases, the Swedish Authority strongly recommended the manufacturer make corrections in documentation.

Conclusions

As frequency converters have become more common, complaints about emissions caused by them have increased. The high connecting frequency and fast switching of large currents, which are characteristic of AC drives, inherently cause emissions. Despite this, the number of frequency converter units which did not fulfill EMC protection requirements was, to say the least, surprising. Only about 40 % of tested units met standards when installed using accessories delivered with the unit.

Even if these test results were quite bad, it does not mean it is impossible to obviate disturbances from AC drive systems. In most cases, manufacturers can offer good filters designed for frequency converters and potential emission problems can be negated by using proper installation methods. The installation of a frequency converter must be undertaken in accordance with installation instructions. In some cases, manufacturer's recommendations are unclear or near impossible to follow. Especially, with regard to the Swedish results, there were a lot of faults within installation instructions. Installation instructions should always be clear and simply expressed - even for skilled, professional installers!

In most of cases, there where no totally correct accessories retailed with the frequency converter. Manufacturers and importers should take care that when selling frequency converters to customers, they deliver all mentioned accessories or, at least, inform the purchaser of what accessories are required in order to get the drive in conformity with standards.

It is also interesting and important to note that the new draft version of EMC Directive [6] does, in fact, reconfirm all that has been stated in the previous paragraphs with regard to installation instructions and external accessories.

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