EMC testing of physically large power supplies: conducted disturbance measurements using a substitutive method

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Abstract - **Telecom operators and engineers have to deal with EMC measurements for physically large systems drawing several hundred kilowatts. Due to their size, they have to be measured without artificial high current mains networks. The voltage probe method described in the standard CISPR 16-2 [1] has to be applied. Unfortunately, the results depend on the test set-up.**

In this paper, we present a new approach and the results of the described measurement method. This method drastically reduces the uncertainty and set-up dependent errors. Moreover matching the line impedance at each port is also a goal.

I. THE PROBLEM, THE CHALLENGE

More and more the Telecom and the IT infrastructures converge. Moreover the power density increases dramatically finally the planner has to deal more with costs and less with system performances.

Rooms and surface are expensive; coexistence between exchanges, IT infrastructure and the power supply equipment has to be insured. Due to the high power needed from the different cabinets, the costs of cabling and the power losses, the power supply (UPS) moves even near to the equipment.

Today we have up to 20 kW of power losses per cabinet.

The planner of such equipment has to deal with functionality, EMC, air conditioning and environment standards. The spacing between equipments will be even smaller (Figure 1) and finally disappear in the near future. In some cases no spacing at all is available between telecom equipment, IT infrastructure and UPS. It is then critical that the compatibility levels between emission and immunity are insured, for the whole system.

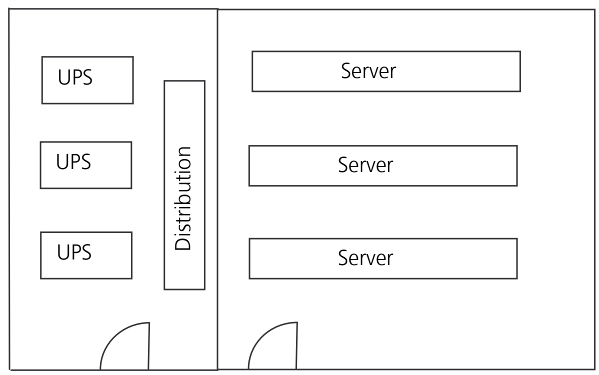

Figure 1: Typical IT server room topology

There is a discrepancy between standards for telecom equipment (ETSI EN 300 386 [3], CISPR 22 [5]) and for UPS (IEC 62040-2 [4]). ETSI EN 300 386 [3] has to be applied in Telco rooms e.g. exchanges and transmission, where the cabling and bonding is or it is supposed to be well known.

Let consider the conducted emissions case: large UPS may have conducted emissions that are higher than the minimum immunity required for Telco equipment.

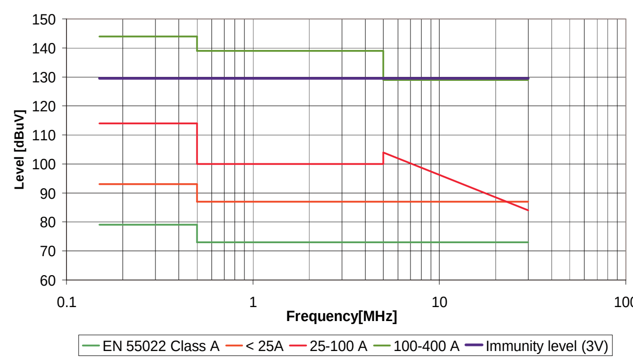

Figure 2: Comparison of emission limits to the 3V immunity level

Figure 2 shows the EMC limits for conducted disturbances to be applied compared to the ones of the UPS standard. A gap between emission level of the UPS and immunity of the Telco or IT equipment should be guaranteed. Measurements have shown that it isn't enough to place the UPS in the cellar to avoid this problem. 80m of power cable are insufficient to attenuate the disturbances of the UPS.

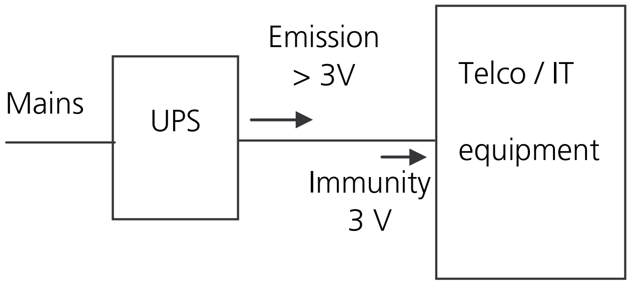

Figure 3: EMC flow diagram from the source to the equipment

ETSI EN 300 386 [3] defines high emission (EN 55022 Class A / CISPR 22 Class A) and low immunity (EN 61000-4-6: 3V [6]) for Telco equipment. The compatibility level gap of 50dB seems to be large. In fact, the power distribution node between the output of the UPS and the input of the IT equipment are connected. All equipments should meet the conducted emissions of class A. How disturbance voltages are combined in this node isn't well known. In practice statistical values are considered to cover this issue. It results that the gap of 50 dB is by the end very small due to the large amount of equipment connected.

In general, EMC labs have only to verify standard conformity. However the goal of our EMC laboratory is to ensure that the compatibility levels between the interconnected equipments are respected. Only doing this, the whole system can work properly.

The economic situation presently forces planning and engineering people to take UPS and power supplies off the shelves and install anywhere where needed without taking care of possible interference problems.

In order to minimise this risk, we have deeply analysed the problem of measuring the conducted disturbances in high power connections and developed a substitutive method based on the CISPR 16-2 [1] standard.

II. Impedance Matching

The key point in the conducted disturbances measurement is the matching of line impedance. In the normal case, this is insured by the AMN. The impedance value is 50 ± 10 Ω in the frequency range from 150 kHz up to 30 MHz. Only few AMN are able to carry currents up to 200A per phase. For higher currents, no AMN are available.

One solution would be to use long lines trying to match with the 50 Ohm impedance.

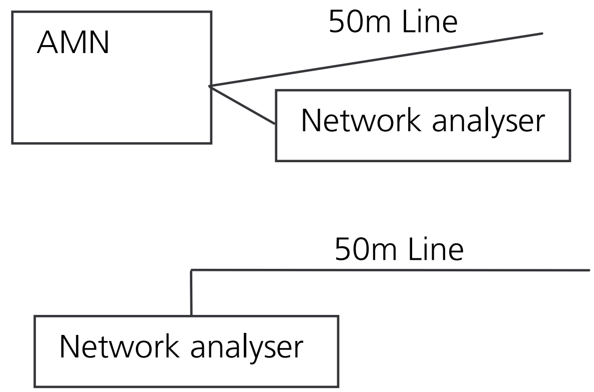

Figure 4: Impedance measurement set-up

The impedance of a 50m mains cable were measured based in the set-up shown in Figure 4.

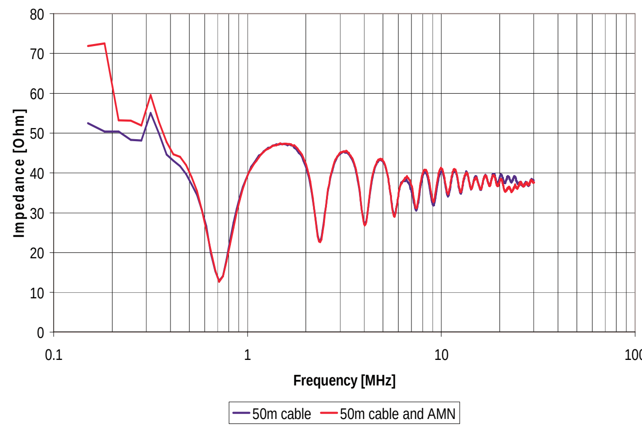

Figure 5: Impedance comparison with and without AMN in parallel to the mains cable (50m)

Figure 5 show the measurements result of the impedance to ground of a 50m long cable alone and with an AMN in parallel. The resonances depend on the line's length.

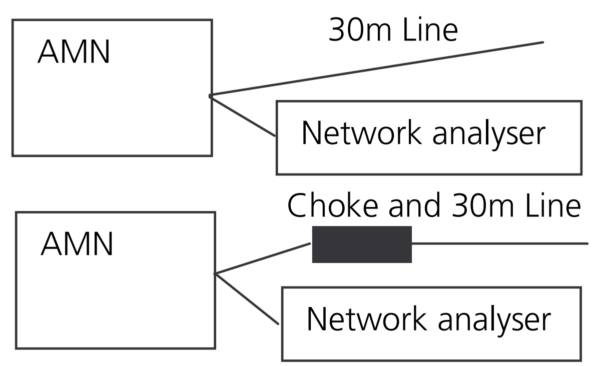

Figure 6: Impedance measurement set-up

Figure 7 shows the typical impedance to ground of a 30m mains supply cable having a cross section of 70mm^2 with an AMN in parallel. The measurement was recorded with and without a decoupling inductor as shown in Figure 6. This method is also described in CISPR 16-2 [1]. Note that the resonance frequency changes with the line lengths.

If the current is higher than 500A, it isn't even possible to realise the decoupling with chokes. For example: a single 30µH air coil capable of carrying 600A is 1m long and have a diameter of about 30cm. It is made of 18m (150mm^2) wire.

Our practical experience shows that the use of long lines is sufficient in most cases. Unfortunately it is sometimes necessary to add capacitors in the middle of the line. In that case, the impedance may decrease but remains more stable.

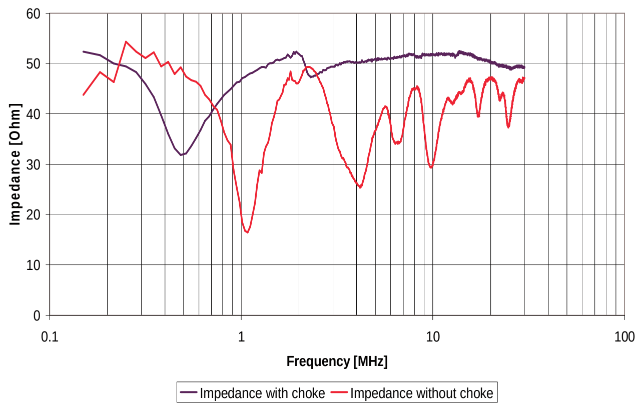

Figure 7: Impedance comparison with and without decoupling choke. Set-up of Figure 6

As shown in Figure 5 and Figure 7, it is important to know that the mains impedance in the frequency range between 150 kHz and 30 MHz remains always below 50 Ohm due to the capacity to ground.

As known from EMC measurements, it is very important to match all lines connected to the device under test. A more reproducible set-up is then guaranteed.

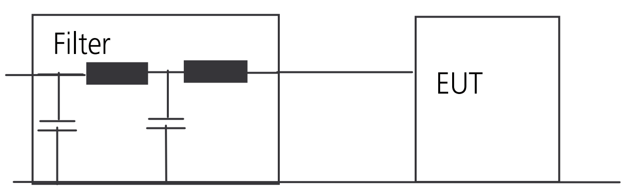

Figure 8: Arrangement with filter

It is also possible to introduce an EMC filter as shown in Figure 8 to reduce the background noise when performing in-situ measurements. In that case it has to be insured that the filter has no capacitors on the side of the equipment under test. In this way the input impedance of the filter is used as additional decoupling impedance.

III. THE APPROACH AND MEASUREMENT METHOD

What does the standardization say?

The basic measurement set-up and method are described in CISPR 16-2:2003 [1] in chapters 2.4.4.4.3, A.5 and are illustrated in Figure A.8. Requirements for measurement without AMN are given in chapter 2.4.4.4.2. However they are very restrictive and almost impossible to be applied.

EMC measurement without an artificial mains network (from CISPR 16-2 [1])

During testing of equipment which cannot be measured with artificial mains networks, the disturbance voltage is measured across a defined simulation resistance. The disturbance voltage is measured with a high-impedance voltage probe.
This is valid also for e.g. power electronic devices which are fed from their own separate power supplies or battery devices to which separately installed lines are connected which are not to be loaded.
In the case of disturbance voltage measurements on separate individual power sources for currents of more than 25 A (e.g. battery, generator, converter), an impedance measurement must be applied to ascertain that the tolerance of the simulated resistance, in accordance with CISPR 16-1 is not exceeded.

The flexible ground connection for probes with an input impedance Rx of more than 1 500 Ω should not be longer than 1/10 of the wave-length at the maximum measurement frequency and shall be connected in the shortest possible way to the metal surface serving as reference ground. In order to avoid additional capacitive loading of the test point by the screening of the probe, the tip of the probe should not exceed a length of approximately 3 cm. The screened connections to the measuring receiver must be arranged in such a way that the capacitance of the test object is not altered with respect to the reference ground.

Artificial mains network as voltage probe (from CISPR 16-2 [1])

Where the current rating of an EUT exceeds the rating of available AMNs, the AMN can be used as a voltage probe. The EUT port of the AMN is connected to each of the supply lines of the EUT (single or three phases).
Prior to connecting an AMN to the mains supply, it must be safely connected to the local physical earth PE.
In the frequency range of 150 kHz to 30 MHz, the supply lines of the EUT shall be connected to the mains via an inductance of 30 µH to 50 µH (see CISPR 16-2 figure A8, configuration 2). The inductance may be realized by a choke, a line of 50 m length or a transformer. In the frequency range of 9 kHz to 150 kHz a greater inductance will normally be required for decoupling from the mains. This guar-

antees also a reduction of noise from the mains network (see CISPR 16-2 A.5).

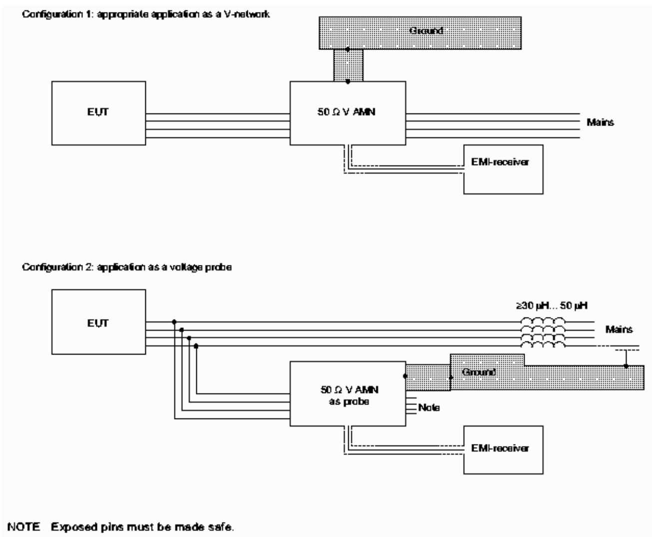

Figure 9: Measurement set-up proposed in CISPR 16-2 figure A.8

Since measurements are preferable with AMN in their standard configuration, the AMN as a voltage probe should only be used for in situ tests and where practical current limitations are exceeded. It shall not be used for testing according to a product standard unless it is referred to in the product standard as an alternative measuring method.

Connection of the AMN as a voltage probe (from CISPR 16-2 [1])

Conducted emission measurements of EUTs with high operational currents may cause difficulties. AMNs for the frequency range 9 kHz to 150 kHz (30 MHz) are available to approximately 25 A nominal current. AMNs for the frequency range 150 kHz to 30 MHz (50 µH parallel to 50 Ω) are available to approximately 200 A. EUTs with higher current rating may be tested using the AMN as a voltage probe. This alternative solution is also helpful for in situ measurement, if referred to in the applicable product standard.

IV. THE PRACTICAL POINT OF VIEW

The use of voltage probes doesen't gives any impedance stabilisation

One of the great challenges with the measurements with a voltage probe is the set-up and impedance uncertainty which can be very large as shown in the Figure 5 and Figure 7. Measurement differences of several dBs are possible. It is also very difficult to reproduce the measurement at another location test sites due to the different mains impedance.

AMN's used as voltage probes improve the line stabilisation and match with the minimal line's impedance

When AMN's are used as voltage probe, the three following conditions will be met:

- Line impedance below 50 Ohm
- Better measurement reproduction
- Same geometry and set-up

V. MEASUREMENT PROCEDURE

The method has been applied for more than 10 years in the measurements of DC power supplies for telecom applications.

However the steps presented [2] hereafter have to be followed in order to obtain more reliable results.

- Be sure that the AMN is connected to ground by a very low impedance. A measurement of the background noise without any connected equipment should be taken. A minimum of 20 dB margin to the limits is mandatory.
- Check the impedance of the measurement set-up (Figure 10) with a spectrum analyser and a tracking generator or a Comb Generator like a RefRad. Before taking measurements, be sure that the generator is decoupled from 230V mains with a high pass filter. In the other case, the output of the generator will be damaged.

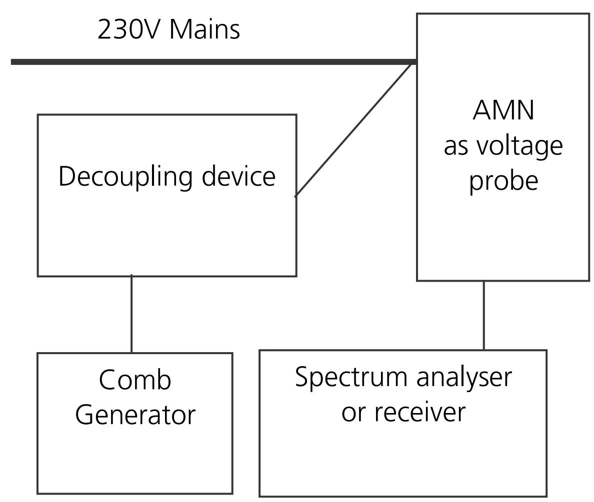

Figure 10: Set-up to verify the impedance matching

- If necessary add an air choke on the mains for matching 50 Ω ±10 Ω and eliminate resonances (Figure 9).
- Perform the first measurement with the AMN normally connected with the current flowing through at the maximum permissible load (e.g. by 25 A)

- Change the set-up according to Figure 9. Perform a measurement using the AMN as a voltage probe at the same load with the same connected cables in the same geometry between AMN and the device under test.
- Compare the results of both measurements
- If the measurement is equal in the trend without any significant differences you can proceed with the measurements at higher load.
- If there are significant differences check again the impedance of the set-up and verify all the ground connections.

The method is used to test conducted emissions at high power (>120 kW) where the limitation of the test site is given by the highest available current in the lab and the highest voltage sustained by the AMN.

VI. PRACTICAL MEASUREMENTS EXAMPLES

The two following examples show the application of the measurement method. They have been chosen to illustrate the set-up and the results.

The first example show the measurement on the mains input of a UPS.

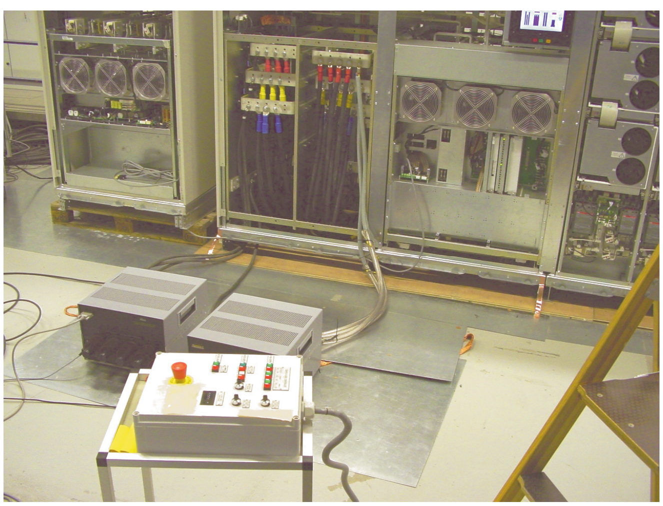

Figure 11: Measurement set-up with the AMN connected as a voltage probe at the mains input and output

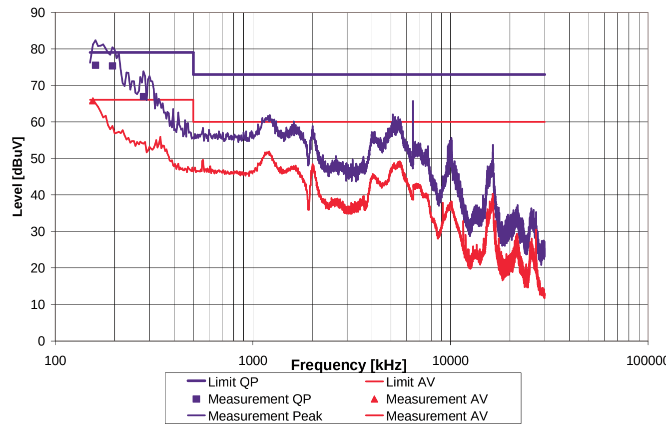

Figure 12: Measurement results on the AC input of the UPS by 800kW load.

The phase current is about 1100 A and the power supply is separated of the rest of the plant with its own transformer.

The second example show the measurement on the DC out-put of a 48V Telecom power supply.

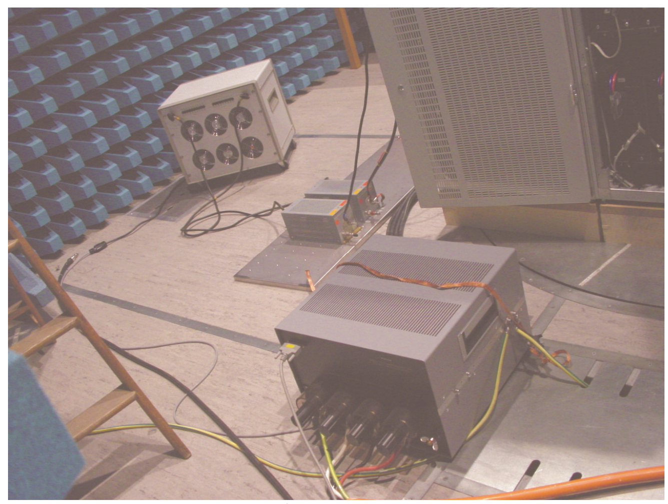

Figure 13: Measurement set-up for measurement on the DC output

It has to be noted that the 2 small AMN placed on the output for the measurement, are loaded with a separate resistive load of 100A. The rest of the load, (1900A) goes directly on the load bank through 2 x 400mm^2 copper bars each pole.

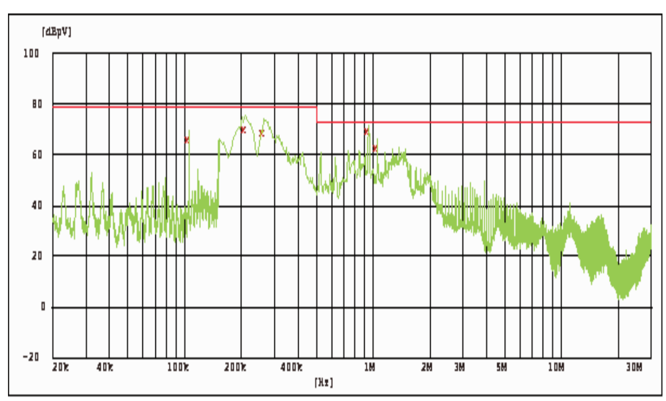

Figure 14: Measurement results on the 48V DC output by 2000A load

VII. ADVANTAGES

The presented method has the following advantages against the voltage probe method:

- No limitation of the drawn current due to the low AMN current capability.
- Stable set-up and reproducible results for both: in-situ and laboratory measurements.
- Comparison between laboratory and in-situ measurements is easy.
- In-situ measurements are possible without mains interruption (Take care of the safety requirement working with high voltage).
- The acceptability of the measurements results is high.
- The results are affected from a lower uncertainty (typical up to 3 dB) against the voltage probe method.

VIII. DISADVANTAGES

It is important to point out that the method has not only advantages.

- The method requires experience in EMC measurement for high power systems and handling of high current.
- Importance of calibration of the test set-up to avoid resonances and false results
- Take care about of inrush currents, load steps, turn on and transient on the measured lines.
- Never work without a pulse limiter on the receiver cable.
- Set-up and measurements takes longer than measurements with the voltage probe but is more reliable.
- One step more is introduced in the method but you can compare the results and decide if you can proceed.

IX. CONCLUSIONS

The presented substitution method is a cost effective and reproducible measurement method for conducted EMC measurements of systems using high power.

X. REFERENCES

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[5] CISPR 22 Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement

[6] EN 61000-4-6: 1996: Electromagnetic compatibility (EMC) - Testing and measurement techniques - Section 6: Immunity to conducted disturbances, induced by radio frequency fields