EMI OF EMISSIONS IN THE FREQUENCY RANGE 2 kHz - 150 kHz

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ABSTRACT

The given gap of standardization for conducted and field coupled electromagnetic interferences (EMI) in the frequency range from 2 kHz up to 150 kHz actually leads to several cases of EMI caused by upcoming power electronics (converters, inverters etc.) and smart meters' powerline communication operated in Cenelec A-band. A group of Cenelec experts systematically analyzes reported EMI-cases to provide support to standardization committees for closing the gap.

INTRODUCTION

In Europe, upcoming smart metering and smart grid systems are largely operating a powerline communication (PLC) system for their information transmission, using frequencies in the range from 3 kHz to 95 kHz, thus using the so-called Cenelec band A of EN 50065-1[1]. Such PLC signals are intentional emissions within a line conducted signalling system, operated

- for monitoring or controlling the low-voltage distribution network, including energy usage of connected equipment and premises (Cenelec band A) or
- for applications within homes, commercial and Industrial premises or for controlling and monitoring equipment connected to the low-voltage distribution network external to premises, like street lighting control or electric vehicle charging (Cenelec bands B, C, D)

with operating frequencies, maximum signal levels as well as with limits for spurious emissions outside the operating frequency band being defined in EN 50065-1 [1].

Non-intentional emissions are mainly caused by different sorts of non-communication equipment using power electronics like inverters and switched-mode power supplies, with

- switching frequencies of some tens of kHz ,
- peak levels of typically up to 100 dBµV and sometimes even higher,
- harmonics of switching frequencies as well as such ones caused by responses of non-linear equipment.

Today, although considering equipment and installations, which have proven conformity with the essential requirements of the related Directives and are therefore legitimately CE-marked, some high potential for interference between different sorts of such equipment is given.

Following to some first cases of EMI between automated meter reading systems using PLC (AMR-PLC) systems and other electrical equipment like touch-dimmer lamps and power inverters, some five years ago, investigations have been started on the electromagnetic (EM) interaction between electrical equipment in general and between such and mains communication systems (MCS) in particular.

CENELEC SC 205 A Mains communication systems set up a Task Force to document and study related EMI cases having been reported from several countries. The focus of the Task Force is to investigate this specific EMC problem, by

- gathering broader information about related EMI cases and the different sorts of equipment involved
- analyzing the reported EMI cases concerning the interference effects and mechanisms,
- identifying a possible gap in standardization for the considered frequency range and to support its closure.

First results have been published with a related Cenelec Study Report, 2010 [2]. Recently, a second edition is in finalization by Cenelec SC 205A.

INTERFERENCE MECHANISMS

As main origins for related EMI, there were recognized

- discontinuous components with a sudden rise of signals or of non-intentional emissions and lacking immunity of electrical equipment to such
- immunity of electrical equipment not considering the specific characters of emissions in this frequency range.
- insufficient signal/noise ratio (see EN 50065-1 [1], Fig 7).
- simultaneous, uncoordinated use of – more or less identical - frequencies in the considered frequency range for intentional signals (AMR-PLC, broadcast time-signal systems like DCF77) and non-intentional conducted emissions, which may cause EMI also via the resulting magnetic field.

The factual number of EMI cases is to be estimated at a higher order by far than those ones made available for investigations or even for initiating changes in standardization, as that requires that

- the degradation of performance or loss of function of some electrical equipment was recognized by a network user as being caused by an EMI

and

- a network user establishes an association between a given interference effect and any changes in the related supply area, e. g. after the installation of AMR-PLC by electricity supplier

and

- the EM interference case was reported to the electricity supplier, by a complaint – directly or via the deliverer –

and, finally,

- such EMI cases are brought to the knowledge of

related standardization bodies.

Fig. 1 and 2 show examples of non-intentional emissions and for signals as before-mentioned.

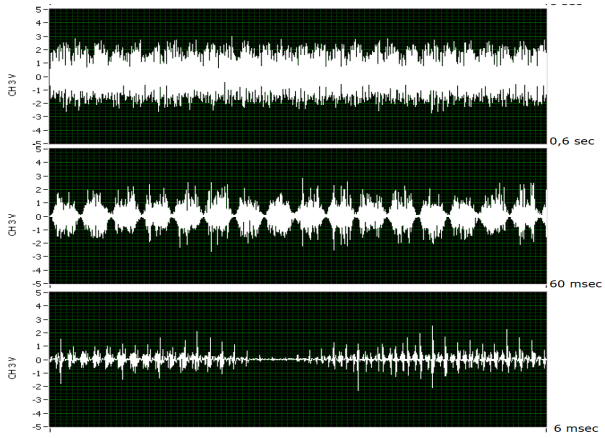

Fig. 1: Example of non-intentional emissions from non-communication equipment

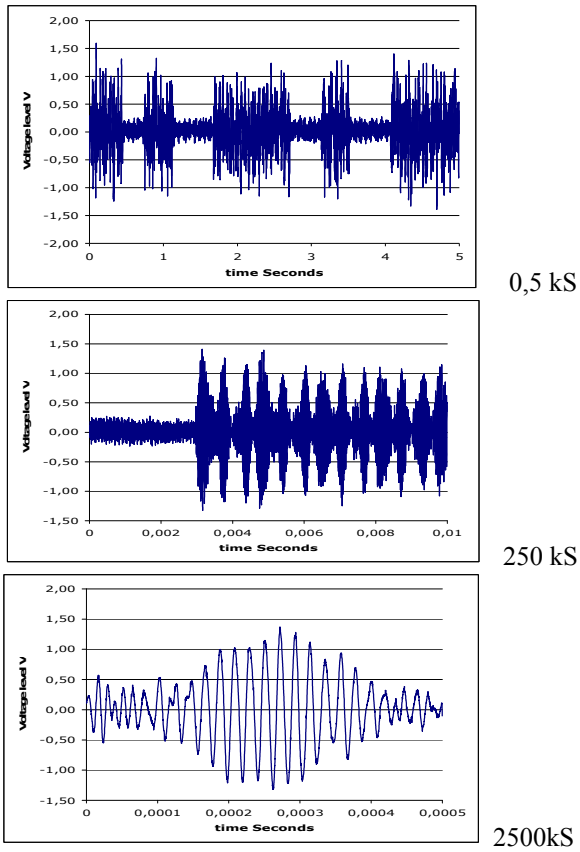

Fig. 2: Example for discontinuous signal of an AMR-PLC system

The spectrum of electrical equipment involved in such EMI cases is to be estimated as being quite larger than that one considered at first sight, so that a more general electromagnetic compatibility (EMC) – and power quality (PQ) - problem appears to be given.

When viewing at the now known portfolio of equipment having been reported from several countries as having been involved in related EMI cases, AMR-PLC are figuring as interference source as well as an EMI victim, but as one sort of electrical equipment out of a quite larger quantity.

Research on the cumulative effect of simultaneous operation of equipment generating such emissions shows a nonlinear effect. This effect was investigated in detail in Sweden, where emissions from some numbers of lamps in a lightning installation were investigated [7].

As an essential example for related EMI sources, switched-mode power supplies, be it incorporated in some device or external, have been recognized, representing a potential EMI source in a lots of EMI cases – also and in particular with dried out smoothing capacitors.

The sensitivity of electrical equipment to EM disturbances appears to be determined not only by the level domain but also by the time domain, i.e. by the current / voltage shape of emissions, in particular by discontinuous current / voltage components in the supply voltage.

Existing standards consider the frequency range below 150 kHz and its specific EM characteristics only to a quite limited extent, resulting amongst others in a lack of standardized limitation of non-intentional emissions from electrical equipment, contrary to the existing standardization building (emissions, immunity) for narrow-band MCS.

As EMI cases with

- emissions from a UPS of a traffic control system interfering to the radio signal of the supplied traffic control system or
- AMR-PLC signals on the mains interfering to the reception of the DCF77 signal used e.g. in a heating control

show, besides conducted emissions also interference through the radiated magnetic field strength stemming from conducted signals or non-intentional emissions is to be considered.

Related EMI does not occur only due to lacking standardized emission or immunity requirements but also due to ageing effects of some single component of an equipment which, as such, has met the related requirements before, at the time of declaring conformity with the essential requirements of the EMC Directive; that highlighting that besides some technological design reasons also a change of the technical characteristics of a device over time may cause EMI.

Summarizing, EMI in this frequency range appears not to be a specific problem related to AMR-PLC, but having a rather broad relevance for EMC with regard to this specific frequency range, nevertheless representing some thread for the existing application and future roll-out of AMR-PLC systems for smart grid purposes.

MEASURES FOR ACHIEVING EMC

In practice, network users are not interested in more or less sophisticated explanations why such EMI occur. Together with merchandisers, they trust in the CE mark, thus deducing an appropriate quality of the products, ensuring proper operability of such equipment, and do not see any reason for taking mitigation measures, in particular on their

cost.

From several options for achieving interference-free co-existence in future, an appropriate choice were to be made with regard to the given priorities for electricity supply and application and economic aspects. Technically, when evaluating mitigation measures (e.g. filters), avoidance of a possible shunting effect to PLC-signals is to be ensured.

On international level there are considerations made to extend the frequency range for such narrow-band applications to 500 kHz, what would provide the basis for somehow more band-with as well as for avoiding or at least reducing potential for EMI from other, non-communication electrical equipment. For Europe, according to existing long-wave broadcast services, amongst others used for flight surveillance and for military communication systems, and therefore due to related radio regulations, such extension to 500 kHz is not possible at present.

In several cases, quite simple measures led to an EMC conform co-existence of different devices having interfered to each other before; as an example an EMI case with a UPS interfering to a contactless magnetic card reader may be mentioned, where installation of shielding steel plates behind and above the UPS and a shielding enclosure for the card reader was successful.

There may be sound reasons for leaving mitigation up to case-by-case solutions, but for the major part of equipment to be considered as potential EMI sources or victims, standardized specifications appear as being needed to economically cover the problem.

EMISSION LIMITS

Up until now, with exception of emission limits

- for harmonics up to 2 kHz (EN 61000-3-2 [3]) and for voltage fluctuations (EN 61000-3-3 [4]) as well as
- for cooking appliances (EN 55011 [5]), and for lighting equipment (EN 55015 [6]) for the frequency range 9 kHz to 150 kHz

no standards limiting non-intentional emissions in the frequency range below 150 kHz have been established up until now. Fig. 3 gives an overview of available standards and shows peaks of emission spectra measured at 40 devices (each represented by a dot or a group of dots connected by a line).

Likewise, this frequency range has been considered for setting standardized immunity requirements only to a limited extent, not covering the whole field of EMI phenomena occurring on the electricity supply network of today.

Therefore today, also when using equipment and installations, which have proven conformity with the essential requirements of the EMC Directive and are therefore legitimately CE-marked, there is some potential for interference between some sorts of such equipment.

To ensure proper communication via PLC in Cenelec A-band according to EN 50065-1 [1], emission limits should be set with regard to the existing limits for spurious out-of-band emissions given by the same standard.

Fig. 3 shows non-intentional emission levels measured during investigations on different devices.

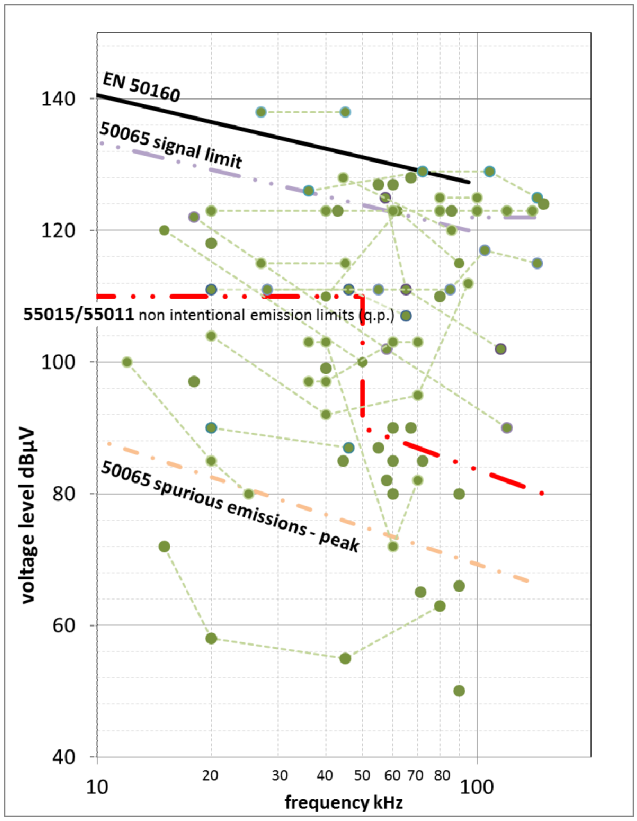

Fig. 3: Emission levels measured at different sorts of equipment, ~~from 40 devices~~ compared with limits for non-intentional emissions and signals as well as PQ levels in present standards

IMMUNITY REQUIREMENTS

For achieving EMC, also an appropriate immunity of devices from signals and from non-intentional emissions, in particular with discontinuous waveshapes and also in differential mode, needs to be considered.

That were to be supported by considering the specific EM characteristics of this frequency range in standards for compatibility, emission limitation, immunity requirements and testing. Immunity requirements should be generally set above the highest specified emission limits, with consideration of the cumulative effect of equipment/systems according to their expectable application.

CONCLUSIONS AND OUTLOOK

It appears as a key issue for providing a future-proof solution for safeguarding EMC in this frequency range in general and for further deployment of PLC systems at realizing smart meter systems and smart grids in particular, to work on related solutions for co-existence in the frequency range 2 kHz to 150 kHz and on related standards; that not solely focused on PLC application for smart metering and smart grids, but considering the full range of electrical equipment which

- are proven to be involved in related EMI cases or
- may be assumed as to be considered with regard to its emissions of or susceptibility to current/voltage components in this frequency range.

That will require to proceed with investigations on the interference issue and

- to close the gap in standardization related to the phenomena being responsible for the EMI in question – as having been started in the meantime, thus further developing a completion of the standardization building (EMC & Product standards) with regard to these phenomena; that ensuring
  - proper function of MCS as well as
  - co-existence between MCS and non-communication equipment
- to appropriately review the rules for using frequencies in the range below 150 kHz. Thereby, it might be advisable to set limits for emissions from non-communication equipment with consideration of
  - an appropriate margin to signal levels from PLC systems in the supply network
  - the standardized limits for non-intentional, spurious emissions from PLC systems

Further

- a separation in terms of part frequency ranges or
- establishment of some chimney concept

are options for ensuring co-existence.

Finally, a review of

- installation rules with consideration of mitigation measures having provided mitigation in several of the described EMI cases
- specifications for the choice of electronic components, with regard to ensuring an undegraded performance during the expectable lifetime of related equipment

appears as being advisable.

Following to the above-mentioned Study Report 2010 of Cenelec, further investigations are under way within Cenelec, in cooperation between universities, test houses, network operators, manufacturers and consultants,

- to extend knowledge
  - on sorts of equipment involved in such EMI cases, as an interference source or victim
  - on related EMI effects and mechanisms
- to increase consciousness on a more general EMC problem not being focused on AMR-PLC only.

A description of the related investigation results is envisaged to be provided with a Cenelec Study Report II; this report will amongst others provide information about EMI cases having been reported from several European and also overseas countries and following to that having been investigated.

As having been started in the meantime concerning compatibility levels and test methods, within the forthcoming years several (EMC and Product) standards will need to be reviewed for related completion or for getting established, taking into account the results of related investigations.

Based on a completed standardization building, also providing the necessary test setups and methods, after some transition period, CE-marked products should comply with appropriately completed standards, considering related emission limits and immunity requirements taking account also of the specific characters of emissions in the frequency range 2 kHz to 150 kHz, thus ensuring

- EMC between electrical equipment also for this frequency range in general
- undegraded operability of MCS in particular, thus supporting the further deployment also of smart metering and smart grid systems using the supply network for related information transmission.

REFERENCES

[1] EN 50065-1 :2011 Signalling on low-voltage installations in the frequency range 3 kHz to 148,5 kHz – Part 1: General requirements, frequency bands and electromagnetic disturbances

[2] SC205A/Sec0260/R, April 2010: Electromagnetic Interference between Electrical Equipment / Systems in the Frequency Range below 150 kHz

[3] EN 61000-3-2:2006 + A1:2009 + A2:2009 Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)

[4] EN 61000-3-3:2008 Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection

[5] EN 55011:2007 Industrial, Scientific and Medical (ISM) Radio-Frequency Equipment -- Electromagnetic Disturbance Characteristics -- Limits and Methods of Measurement (CISPR 11:2003 + A1:2004, modified + A2:2006)

[6] EN 55015:2006 + A1:2007 + A2:2009 Limits and methods of measurement of radio disturbance characteristics of Electrical lighting and similar equipment (identical with CISPR 15:2005 + A1:2006 + A2:2008)

[7] A. Larsson, M. Bollen Emission (2 to 150 kHz) from a Light Installation, CIRED 21st International Conference on Electricity Distribution 2011, Paper 0250

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