EMI in the Frequency Range 2 - 150 kHz

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Abstract— Emissions from general, non-mains communicating equipment (NCE) as well as signals from Mains communicating systems (MCS), when utilizing the frequency range from 2 to 150 kHz, are capable to cause electromagnetic interference (EMI) to other electrical equipment. Consideration of related electromagnetic compatibility (EMC) problems was limited in standardization up until now. With regard to the recognized gap, the occurrence of quite high emission levels in electricity supply networks and, due to that, of EMI is to be seen; that with different types of electrical equipment being involved and with increasing tendency of occurrence to be expected.

A group of Cenelec experts gathered measurement results on existing emission levels in electricity supply networks and cases of EMI between different types of electrical equipment, to provide support to standardization for closing the gap.

Keywords: 2–150 kHz; emissions; electromagnetic interference; frequency utilization; standardization

INTRODUCTION

Following the occurrence of first EMI cases, some years ago, with involvement of an automated meter reading system using PLC for information transmission (AMR-PLC) as an interference source and touch-dimmer lamps (TDL) as a victim, Cenelec SC 205A started investigations on EMI in the frequency range 2 – 150 kHz. A related Task Force was set up to investigate this specific EMC problem, for gathering information on existing emission levels on the supply networks and on related EMI cases, effects and the different types of equipment involved; that for checking the given related network reality, analyzing reported EMI cases concerning the interference mechanisms and for checking available standards concerning a gap related to the considered frequency range, aiming at providing support to its closure.

First results have been provided with a related Study Report, 2010 [1]. Already at that time, the assumption was made, that more types of electrical equipment could need to be considered as being capable to generate emissions with disturbing effect to other equipment or to be susceptible to such.

In 2013, SC 205A provided a 2nd, extended edition of this Report [2].

Now, a 3rd edition is under way, aiming at further extension with information obtained in the meantime. Establishment of a related Cenelec Technical Report (TR) is under consideration.

BACKGROUND

Some decades ago, the frequency range below 150 kHz, actually from 2 to 150 kHz, was not an issue for consideration concerning utilization of this range and EMI. This has considerably changed, on the one side due to increasing application of electronic control in electrical equipment and power electronics, on the other side due to application of narrow-band PLC systems using the mains for information transmission, according to IEC 61000-3-8 [3], 61334-3-1 [9] / EN 50065-1 [4].

Today, we are facing a quite extensive utilization of this frequency range, by several types of equipment; with regard to the technical background of this utilization, there is to be distinguished between

- General, non-mains communicating equipment/systems (NCE),
  - using the electric energy supplied for realizing some service for the network user, amongst those also equipment applying power electronics like inverters and switched-mode power supplies, with
    - switching frequencies of some kHz up to some tens of kHz and its harmonics, causing emission levels at certain frequencies typically up to 100 dBμV and even higher,
    - harmonics caused by responses of non-linear equipment to the switching frequencies,
  - impressing non-intentional current components on the mains, as an inherent consequence of the applied technology, without any information content
- Mains communicating equipment/systems (MCS)
  - using the mains for the transmission of signals, e.g. for operational purposes of the supply network operation or for in-home applications
  - impressing, by intention, signals conveying information on the mains, as the intended purpose of MCS; beyond that, also spurious emissions out of the MCS band are generated.

In Europe, upcoming smart meter and smart grid systems are largely operating a PLC system for their information trans-mission, using frequencies in Cenelec band A (3 to 95 kHz). Such signals are intentional emissions with operating frequencies, maximum signal levels as well as limits for spurious emissions outside the operating frequency band.

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1 European Committee for Electrotechnical Standardization
2 SC 205A Mains communicating systems
being defined in the above-mentioned standards [3], [4], [9].

Emissions from both groups of equipment are capable to cause EMI to other electrical equipment, thus causing disturbing effects to it, when simultaneously using – more or less identical – frequencies in the considered frequency range.

I. ACTUAL EMISSION AND EMI SITUATION

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

Today, although considering equipment and installations only, which have proven conformity • with the available standards and • – for Europe – with the essential requirements (ERs) of the related EU-Directives and are therefore legitimately CE-marked,

some high potential for EMI between several types of such equipment is given.

As the CENELEC Study Report [2] shows, measurements of NIE in the frequency range 2 to 150 kHz show quite high levels,

• either around some certain frequencies (see Fig. 3a))
• or covering a broader frequency range, of several tens of kHz (see Fig. 3b)).

![Fig. 1: Example of non-intentional emissions from NCE (here: metal industry)](image1)

![Fig. 2: Example for discontinuous signal of an AMR-PLC system](image2)

Different types of equipment have been recognized as being involved in related EMI cases, as a source or victim, e.g.

- Lighting equipment, Household equipment, Switched-mode power supplies, inverters and variable speed drives, AMR-PLC as an EMI source
- Electronic control circuits and systems, Communication systems, Magnetic card readers, Medical equipment, Broadcast time signal systems, Mobile radio systems, TV and radio receivers, Amateur radio, Solid state meters, Lighting equipment, AMR-PLC as an EMI victim.

This list may need further completion due to additional investigations. In any case, the occurrence of EMI cases may be assumed being quite larger than at first sight. Lighting equipment as well as AMR-PLC are figuring as EMI sources and as victims, but as only two examples of equipment to be considered.

Research on the cumulative effect of simultaneous operation of equipment generating such emissions shows a non-linear effect.

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

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

As e.g. EMI with broadcast-time signals show, also EMI via the radiated path, via the magnetic field strength stemming from conducted NIE or PLC signals, need to be considered.
As main origins for related EMI, there were recognized
• high levels of conducted emissions up to and exceeding 5 V, thus also being close to or even exceeding the signal injection limits for MCS, due to
  o applied technology
  o lacking or insufficient filtering
  o change of characteristics of electronic components (ageing effect)
  o cumulative effect of several loads
• radiated coupling of related currents on the mains
• insufficient immunity, e.g. from discontinuous emissions, actually to the effect of the envelope of a discontinuous current on the mains (NIE, MCS)
• in case of involvement of MCS: insufficient signal-to-noise (S/N) ratio (see EN 50065-1 [4], Fig 7)
• coincidence of the ever changing loads connected to an installation, resulting in a shunting effect for signals.

Summarizing, EMI in this frequency range can be considered as
• not being an issue mainly related to AMR-PLC; nevertheless, for Europe, such EMI represent some thread for the existing application and the future roll-out of AMR-PLC systems for smart grid purposes
• having some more general relevance for EMC.

II. EMC REQUIREMENTS & STANDARDS FOR 2-150 KHz

Up until now, beyond emission limits for harmonics up to 2 kHz (EN 61000-3-2 [5]) and for voltage fluctuations (EN 61000-3-3 [6]) as well as, for the frequency range 9 to 150 kHz, for induction cookers (EN 55014-1 [7]) and for lighting equipment (EN 55015 [8]), no standards limiting NIE in LV networks in the frequency range below 150 kHz are available.

Likewise, for setting standardized immunity requirements, this frequency range has been considered 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, which
• has proven conformity with the available standards and – for Europe – with the ERs of the Electromagnetic Compatibility Directive (EMCD) and
• are therefore legitimately CE-marked,
there is some potential for EMI.

To ensure proper PLC operation in Cenelec band A, emission limits for NCE utilizing this frequency range need to be set considering a sufficient S/N to the signal levels.

Fig. 4 gives an overview of recently available standards specifying emission limits and PQ levels for the considered frequency range, together with a summary of emission peak levels having been measured in supply networks for Study Report II [2].

III. IMMUNITY REQUIREMENTS

For achieving EMC related to 2 – 150 kHz, also appropriate immunity of devices from NIE as well as from signals is to be considered.

That were to be ensured by considering
• the specific EM phenomena in the frequency range in standards for immunity testing and specifying immunity requirements in Product standards
• the cumulative effect of equipment/systems according to their expectable level of application.

IV. OPTIONS FOR ACHIEVING EMC

In practice, network users are not interested in more or less sophisticated explanations why such EMI occur. Together with deliverers, they trust in conformity with standards and, for Europe, in the CE mark, and do not see any reason for taking mitigation measures, in particular on their cost.

From several options for achieving EMI-free co-existence in future, an appropriate choice were to be made with regard to the given utilization of electricity supply networks, the political intentions concerning energy efficiency, smart metering/grids and economic aspects. When evaluating mitigation measures (e.g. filters), avoidance of a possible shunting effect to PLC-signals is to be ensured.

Sometimes a move of PLC systems to the frequency range 150 – 500 kHz is discussed as a solution. Anyhow, although that would provide an option for avoiding or at least reducing EMI potential between NCE and MCS, such a change -- not to be counted as a technical measure for ensuring EMC in a given environment --
would not solve the general EMC problem between NCE in this frequency range,
is not possible for Europe at present, with regard to existing long-wave broadcast services, amongst others used for flight surveillance and for military communication systems, and therefore due to related radio regulations.

In several cases, quite simple measures led to an EMC conform co-existence of different devices having interfered with each other before; as an example an EMI case with a UPS interfering with 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, in single cases; but for the major part of equipment to be considered as potential EMI sources or victims, standardized specifications appear as being needed to economically cope with the problem.

V. CONCLUSIONS AND OUTLOOK

It appears as a key issue for 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 to 150 kHz and on related standards; that

- considering the full range of equipment recognized to be involved in related EMI cases
- with regard to its emissions of or susceptibility to current/voltage components in this frequency range.

That will require
- to proceed with investigations on related EMI
- to close the related gap in standardization as having been started in the meantime
- to ensure effective rules for the utilization of frequencies in the range below 150 kHz.

Finally, a review of
- installation rules with consideration of mitigation measures having been successfully taken 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.

Further investigations are needed and under way, e.g. within Cenelec SC 205A, in cooperation between universities, test houses, network operators, manufacturers and consultants,
- to extend knowledge on types of equipment involved in related EMI cases, as an interference source or victim as well as on EMI effects and mechanisms
- to increase consciousness on the more general EMC problem, not being focused on AMR-PLC.

At present, a 3rd edition of the Study Report is under way, aiming at providing additional information having been gained in the meantime.

With regard to the ongoing proliferation of electronic control and power electronics in all areas of life as well as of MCS, without taking measures a further increase of EMI cases can be expected. As having been started in the meantime, within the forthcoming years, several (EMC and Product) standards will need to be established or reviewed for related completion, taking into account the results of related investigations.

Based on an appropriately completed standardization building, also providing the necessary test setups and methods, after some transition period, products should comply with the so completed requirements, thus ensuring
- EMC between electrical equipment also for this frequency range in general
- undegraded operability of MCS, thus supporting the further deployment of smart metering and smart grid systems using the supply network for related information transmission.

[3] IEC 61000-3-8 Ed. 1:0:1997 Electromagnetic compatibility (EMC) - Part 3: Limits - Section 8: Signalling on low-voltage electrical installations - Emission levels, frequency bands and electromagnetic disturbance levels
[4] 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
[6] 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
[9] IEC 61334-3-1:1998 Distribution automation using distribution line carrier systems - Part 3-1: Mains signalling requirements - Frequency bands and output levels

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