

## IMPACT OF NON INTENTIONAL DISTURBANCES ON DISTRIBUTION LINE COMMUNICATION

Luca BETTINSOLI  
ENEL Distribuzione S.p.a -  
Italy  
[luca.bettinsoli@enel.com](mailto:luca.bettinsoli@enel.com)

Romano NAPOLITANO  
ENEL Distribuzione S.p.a -  
Italy  
[romano.napolitano@enel.com](mailto:romano.napolitano@enel.com)

Claudia IMPOSIMATO  
RSE - Italy  
[claudia.imposimato@rse-web.it](mailto:claudia.imposimato@rse-web.it)

Paolo GIUBBINI  
ENEL Distribuzione S.p.a -  
Italy  
[paolo.giubbini@enel.com](mailto:paolo.giubbini@enel.com)

### ABSTRACT

*The mains communication systems, or MCS, in recent years had a significant growth and development through their intensive application in the field of the Smart Meter and Smart Grid.*

*However, this communication technology is still suffering for the lack of a not adequate and clear regulation framework, which enabling a not correctly coordinated coexistence with other no communication devices connected to the electricity grid (i.e. led lamps, motors, inverters, switching power supply, etc.). The latter devices, in fact, can generate conducted not intentional disturbances causing harmful interferences.*

*Due to the increasing growth and evolution of electric and electronic devices connected to the power network, the DLC (Distribution Line Communication) troubles are increasing, as they both share the same transmission medium.*

*To reduce the incidence of increasing troubles, a rationale to justify a proper coexistence among MCS and electronic device technologies is given in this paper.*

*DLC now is used in more than 150 million of smart meters around the world and millions of communication nodes in domotic applications, but also smart grids needs, related, for instance, to operation and control issues from DSOs and TSOs could rely partly on this communication system, as it seems not realistic to have a MSC based everywhere on a single specific technology.*

*Due to these changes it was considered important to conduct a study and perform tests, in a controlled environment, which would allow to better understand the joint behavior of network device's users as energy source and devices that use it as a communication channel.*

*The study and tests have shown that high level disturbances injected into the net produce effects which reduce the capability of using the electricity network as transmission medium limiting both the maximum distance reachable between two nodes as well as the channel throughput.*

### INTRODUCTION

Over the years, the electricity distribution network has been subjected to a significant evolution, moving from a 'passive' electricity grid, where the main task was to transport and to distribute the energy, to an 'active' electricity grid. In this context, the new electricity distribution grid ('active' grid) is requested to "convey" the generation also from renewable sources, to be used as a medium of communication, to transport energy, and, at the same time, to guarantee adequate levels of reliability and quality of service.

The idea of DSOs (Distribution System Operator) to update the electricity grid in order to make it a 'smart grid' began many years ago. ENEL, for example, began to experience the remote meter management already in the '90, reaching, in 2011, 37 million of installed and remotely controlled 'smart meters'. The goal of the electricity grid is to become even smarter, moving towards the 'smart grids', as defined by 'EREGG (European Regulators' Association 27):

**Smart Grid is an electricity network that can cost efficiently integrate the behavior and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety.**

Figure 1 schematically shows what ENEL intends to achieve in the coming years from a mains electricity.



Figure 1 – New scenario of ENEL electrical system [1]

At the same time, also the devices interconnected to the network have changed, increased and updated, becoming extremely sophisticated both to improve energy efficiency and to increase their functionality. As an example, Figure 2 shows the transition from the incandescent to the LED lamp technology.

Type of lamp	Operation	Advantages and Disadvantages
	Based on the principle of irradiation of photons generated by the overheating of a metallic element	• Low cost • produces a comfortable light • Large amount of energy lost
	The light produced is based on the presence of mercury vapor and fluorescent material	• Uses less energy and lasts longer • Contains mercury
	The light is the result of the movement of electrons within a semiconductor structure	• Transforms more than 90% of electricity into light • long duration • Expensive

Figure 2: From incandescent to LED lamp technology

The use of this technology leads not only benefits, but also inconveniences, as some of the new electronic devices can inject into the power grid disturbances which are source of serious troubles for DSOs affecting the quality of communication between the data concentrator and the ‘smart meter’.

It appears obvious that the problem is the sharing of the medium: devices that use the electricity grid exclusively for power supply are defined **NCS (Not Communicating Systems)**, while those devices that use the grid both for power supply as well as for transmission are defined **MCS (Mains Communicating Systems)**.

### COEXISTENCE BETWEEN NCS AND MCS

The power grid is regulated and therefore there is a precise allocation of frequencies. Figure 3 shows a macro allocation of frequencies from 0 to 700 kHz, as given by the FCC (Federal Communication Commission) standards.

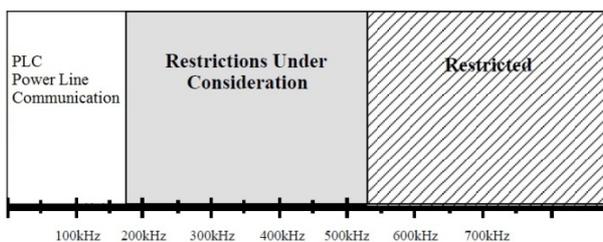


Figure 3: FCC and Industry Canada Frequency Allocation

In Europe the CENELEC allocated, permitted bandwidth to the DSOs in order to transmit is only between **9 and 95 kHz ('A' Band)**, as shown in Figure 4.

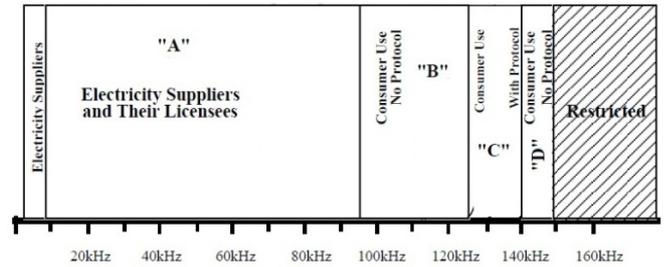


Figure 4: CENELEC Frequency Allocation

The electrical network frequency division is simple in theory, but, unfortunately, it is more complex in reality because each device connected to the network has its behavior and currently there not studies/regulations assessing the behavior of the **complete system** composed by equipment, cables and devices using the network as medium for transmission etc. In addition, due to the lack of compatibility levels in this frequency band, it happens that, in the bands dedicated to MCS devices, there are also the NID (Not Intentional Disturbances) produced by the NCS devices connected to the same network.

Figure 5 shows, the transmitted spectrum of a ‘narrow-band’ (centered at 72 kHz) FSK modulator typically used for smart meter communications. This picture was obtained from a conducted emission measurement (using the CISPR 16 methodology).

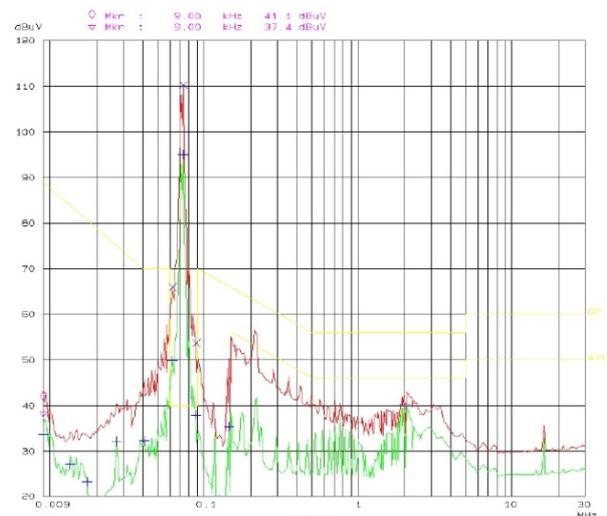


Figure 5: Spectrum of the conducted emissions of smart meter in transmission mode (ENEL)

It’s important to know that the emission levels of the MCS systems are designed to be compliant with **EN 50065-1** [2] in both transmitting and receiving operation mode.

The emission limits in ‘receiving’ condition (condition in which the meter expects requests to send data) are shown in Figure 6 and the limits in ‘transmission’ condition (condition in which the meter sends the data on grid) are reported in Table 1.

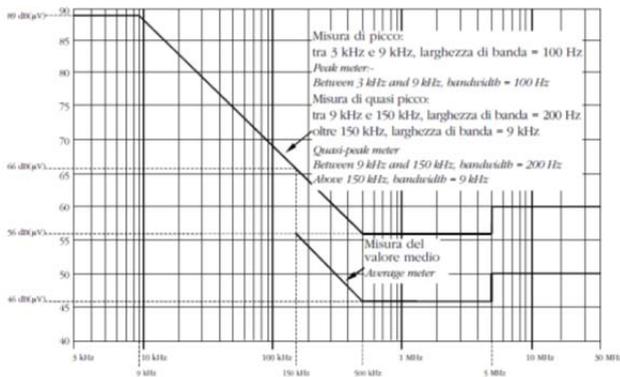


Figure 6: Emission level limit according to EN 50065-1

Sottobanda di frequenze Frequency sub-band	Dispositivi monofase Single-phase devices	Dispositivi trifase Three-phase devices	
		Trasmissione simultanea su tutte le fasi Simultaneous transmission on all phases	Trasmissione solo su una singola fase Transmission on a single phase only
da 3 kHz a 9 kHz	154	128	134
da 9 kHz a 95 kHz (Banda stretta) (Narrow-band)	da 134 a 120*	da 128 a 114*	da 134 a 120*
da 9 kHz a 95 kHz (Banda larga) (Wide-band)	154	128	134
da 95 kHz a 148,5 kHz (Classe Class 122)	122	116	122
da 95 kHz a 148,5 kHz (Classe Class 154)	154	128	134

Tutti i valori limite in dB (μV)  
All limit values in dB (μV)  
\* Diminuisce linearmente con il logaritmo della frequenza  
Decreasing linearly with the logarithm of frequency

Table 1: Transmission mode limits according to EN 50065-1

In this context, the aim of the experimental study carried out in a “controlled environment” was to evaluate the role of some crucial parameters like distance, interference level and network impedance, that impact on the possible coexistence of NCS and MCS connected to the same network.

This controlled environment, located in Milan by CESI, is a facility built to replicate the real electrical system. It consists of 4 substations, one of these is a pole substation, and is composed by 40 km of low voltage cables of different sizes, some overhead and some underground, with junctions where real loads are connected.

The facility simulates a small rural area, about a hundred houses, and small industries. The house simulation has been recreated by using typical domestic loads like different kinds of lamps vacuum cleaners, computers, washing machines, TV sets, etc. Similarly, for simulating small factories there are three-phase loads, such as motors, ovens etc. In this facility, some aspects of the power system can be studied, as the noise propagation, the noise levels, the impedance and the time variation of the system (the parameters like noise and impedance vary during the time).

To carry out the experimental study, only a part of the facility has been used, that is one secondary substation and the longest backbone. Figure 7 schematically shows the set-up adopted to carry out the experimental study.

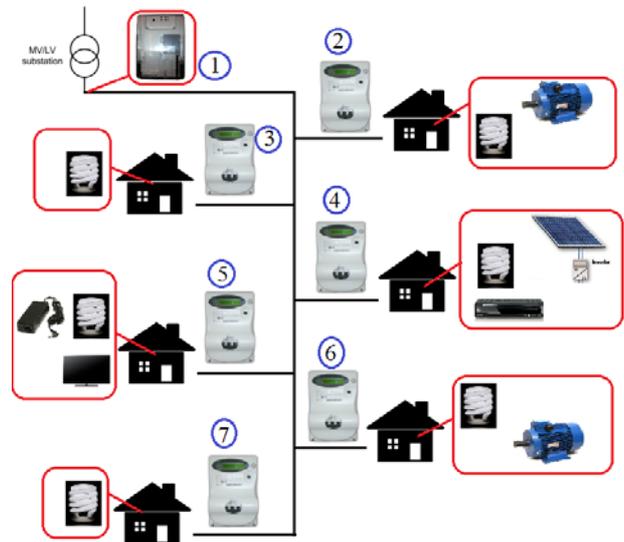


Figure 7: Schematic set-up of network used for measurements

Figure 8 shows the impedance measurements at the points reported in Figure 7, but without any load; when the loads are connected, it was observed that the local impedance modifies accordingly.

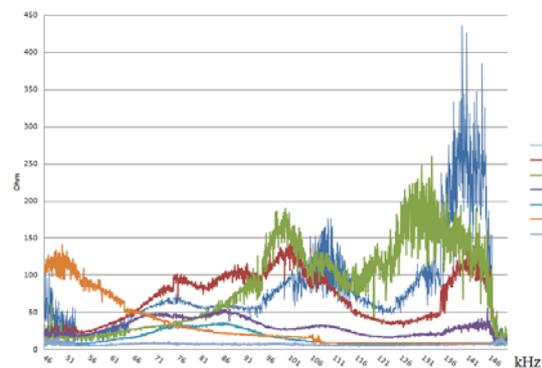


Figure 8: Impedance measurement at different points without loads (ENEL)

The impedance in the secondary substation is quite stable and low (5 Ω) in all the frequency range.

Concerning the disturbances propagation, Figure 9 shows that when the motor, located at point 6 (see Figure 7) is switched on, the disturbances propagate in the remaining points.

To note that, even if the distance between point 2 and 7 is 403 m, no strong attenuation has been registered, particularly at lower frequencies of the spectrum, that is the band reserved to DLC.

In addition, when such a disturbance is present in the network, the communication system of the meter is compromised as disturbance peaks are higher than the values acceptable for the DSO to transmit.

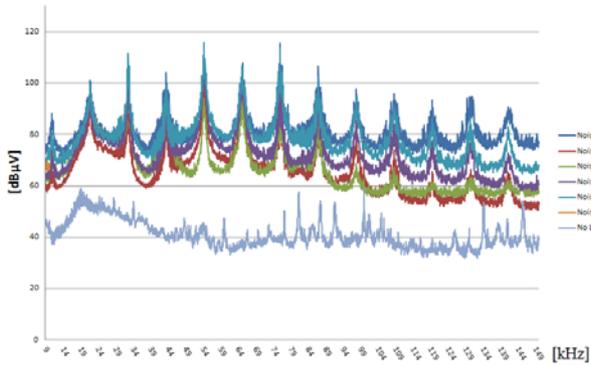


Figure 9: propagation of noise produced only by motor switched on at point 6 (ENEL)

Figure 10 shows the noise produced by **different loads** connected to the network at their insertion point.

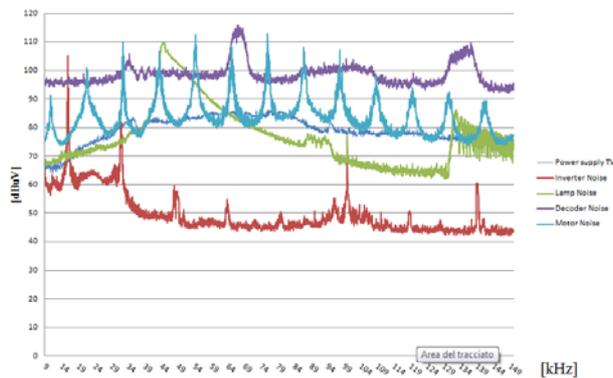


Figure 10: Noise of different loads (ENEL)

Figure 11 shows the composition of the disturbances measured at different points in the network. It is clear that the composition of disturbances is different depending on the distance from the source and the impedance, but it is possible to recognize the different sources of disturbance.

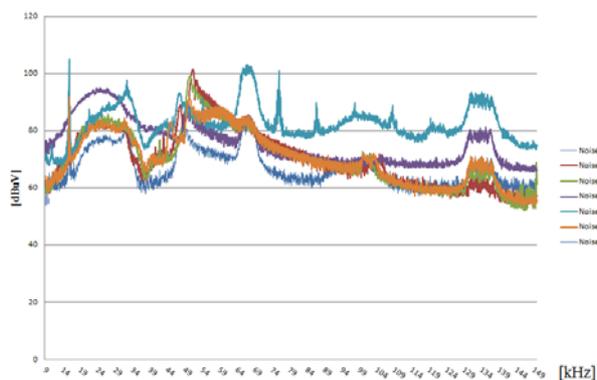


Figure 11: Noise whit all load switched on measured in the 7 points defined in Figure 7(ENEL)

To have a global and comprehensive understanding of the real situation in the network, it is useful to take into

account the possible different combinations of MCS and NCS equipment/systems as in Figure 12.

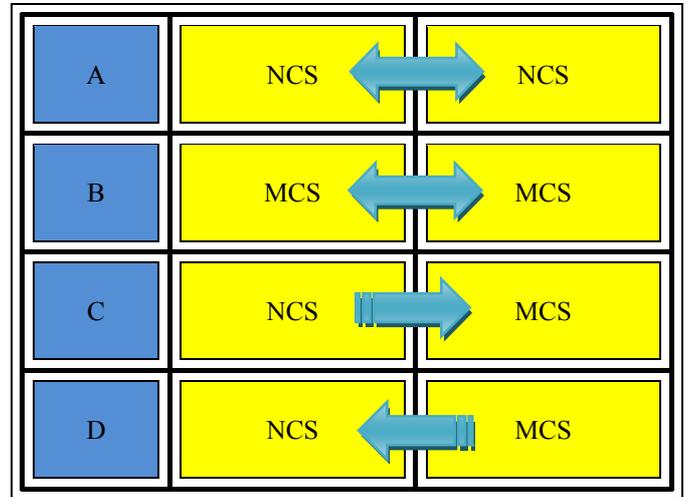


Figure 12: Possible combination of MCS and NCS equipment/systems

**Case A:** only NCS are connected. Among the NCS, as an example, in Figure 12 are reported the different emission level allowed to AIC (Active Infeed Converter) family as in IEC 62578/Ed2/DTS [3].

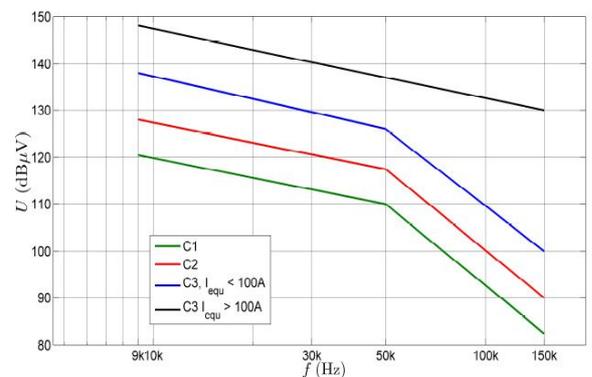


Figure 13: From IEC 62578/Ed2/DTS

**Case B:** only MCS are connected. The devices can be disturbed but, thank to the limited duration of the noise and the protocol inside, it is possible to detect if the channel is busy (that is unable to receive the signal). In this case the signal is delayed but can be re-transmitted later when there are no more disturbances ('channel available').

**Case C:** NCS are disturbing MCS. Differently from case B, the noise is **unpredictable and continuous**, like the noise reported in Figure 8, or the levels reported in Figure 12. In this situation, the channel is permanently busy and the protocol cannot solve the situation.

**Case D:** MCS are disturbing NCS. In this situation the duration of the noise produced by MCS is limited in time

but some coexistence problems are under evaluation.

For DLC, the most crucial case is the **case C**. As the result of the experimental study described in this paper and from daily ENEL experience in the real field, it is suggested, in order to preserve the correct operating meters in presence of disturbing loads connected to the network, to apply:

- for both MCS in ‘receiving’ mode and NCS, the emission limits indicated in EN 50065-1 (Figure 6)
- for the immunity of all the equipment, the limits permitted in ‘transmission’ mode of MCS (Table 1)

In Italy, a group of experts in CEI (Italian Standardization Body in Electrotechnical and Electronic field), including manufacturers and utilities, is working to prepare some guidelines for defining if in some cases, on bases of the common experience, it is possible to apply particular emission levels.

## CONCLUSION

Protecting the communication on low voltage network is particularly important considering the role of the smart meter in the future of the smart grid.

In Figure 14 it is reported the road map of the meters installation in Europe using DLC.

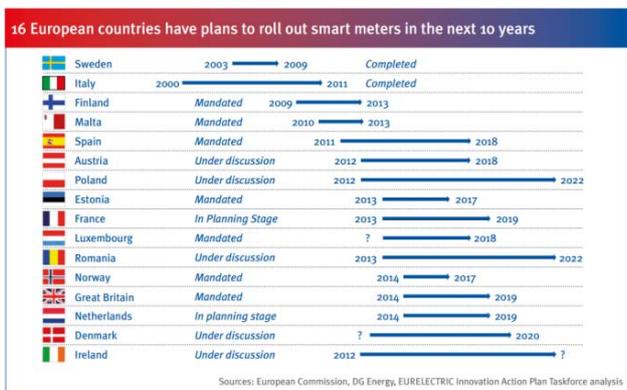


Figure 14: Road map of the meters installation in Europe

The efforts to allow the correct operation of the smart meters have to be increased also to permit the development of remote metering management systems in every European Countries. According to the European Commission mandate M/441 (smart meters mandate) [4], and CENELEC, common DLC standard protocols are permitted in EU Member States [5], but the need is felt in many other areas.

## REFERENCES

- [1] G. Fioriti, 2014, "Il nuovo scenario del sistema elettrico italiano", Rome, *CIGRE Italian National Committee General Assembly*

- [2] EN 50065-1, 2011, Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz. Part 1: General requirements, frequency bands and electromagnetic disturbances
- [3] IEC 62578/Ed2/DTS, 2013, Power electronics systems and equipment – Operation conditions and characteristics of active infeed converter (AIC) applications including design recommendations for their emission values below 150 kHz
- [4] European Commission Mandate, March 2009 M/441, Standardization mandate to CEN, CENELEC and ETSI in the field of measuring instruments for the development of an open architecture for utility meters involving communications protocols enabling interoperability
- [5] CEN/CLC/ETSI/FprTR 50572, Functional Reference Architecture for Communications in Smart Metering Systems