PLC NOISE AND IMPEDANCE MEASUREMENTS ON LOADS AND IN THE DISTRIBUTION GRID

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ABSTRACT

Power Line Communication is still one of the most popular ways to solve the last-mile problem in Smart Metering. The main drawbacks of this medium are the harsh circumstances in the grid. The unpredictability of noise and impedance in the grid makes it a difficult task to model the physical channel and therefore choose the right modulation technique for the job.

In this paper noise and impedance measurements are executed. This leads to a classification of the different types of loads in function of the basic parameters influencing power line communication.

INTRODUCTION

In the CIRED2011 paper 1172, we presented "A Power Line Communication Measuring Toolbox for the Distribution Grid" (PLC Measuring Toolbox). In this paper an overview was given of the capabilities of our in-house developed system.

The PLC toolbox is used to conduct measurements in the distribution grids in Belgium, the Netherlands and Germany. Next to that it allowed us to do measurements on grid components like transformers and cables in an off-grid and connected (installed) configuration. As an example it was identified that in rural areas, PLC communication systems suffer from high series impedance on long overhead lines, while at the substation, the MV/LV transformer represents a rather low impedance. Communication units placed in the substation often have difficulties in applying enough signal power to overcome the combination of both effects in order to reach metering equipment placed on a typical rural feeder in the field. It was seen that impedance and noise are in fact two different problems, both causing communication disturbances. Noise and impedance measurements on consumer electronics were executed using the PLC toolbox and will be shown here.

THE IMPACT OF NOISE AND IMPEDANCE ON PLC SIGNALS

Power Line Communication is one of the solutions for the last-mile-problem for Smart Metering and Smart Grids. In order to support our clients in their pilot projects using PLC, a Toolbox was developed. Long-term monitoring of smart meters in the field gave insights in the communication quality and reliability. The daily and sometimes hourly fluctuations in meter accessibility needed further investigation. In the laboratory we were able to reproduce circumstances that prevent the meters from communicating by lowering the grid impedance or increase the amount of noise injected. The impedance variations are produced by an in-house developed load bench. The noise can be synthesized via our PLC Toolbox but it is also possible to play pre-recorded samples measured in the grid.

PLC TOOLBOX

First, the different building blocks of the toolbox will be explained. The PLC Measuring Toolbox consists of several building blocks who all have their specific purpose and can be combined in various setups. The PLC toolbox contains a computer with a high-end acquisition card to do the measurements in the grid. The card can also emit self-generated signals. Since the measurements are done on the distribution grid, conditioning is needed. For this conditioning and to be able to support different measuring setups while leaving the measurement device in the field, a switchbox has been developed. The setups are a combination of different signals and the switchbox automatically connects the acquisition channel inputs to the signals corresponding to the selected setup. To measure the parameters 'impedance' and 'transfer function' a high-frequency 30W power amplifier has been designed and built to be able to inject signals in the electricity grid. After the acquisition an elaborate software package allows us to do spectral impedance, noise and transfer function analysis.

MEASUREMENTS

Using the PLC toolbox, one is able to measure the fundamental parameters, i.e. impedance, noise and transfer function of PLC signals in the grid. Measurements are performed both in the laboratory and in the field. Since PLC communication for smart metering is situated in the frequency range between 20kHz and 120kHz, the measurements are executed in this frequency interval.

Noise and impedance

Many consumer electronics were measured in the Faraday cage in our EMC laboratory. As an example, the measurements on a Digital TV decoder will be presented. This is a device used for decoding digital television signals to analog signals. It also contains a hard-disk to store recorded television programs. The device is typically fed by an external power supply.

A first figure that gives an interesting view on the behavior of an electric load is the time-domain view (figure 1). The high-frequency voltage (blue) and current (green) and the 50Hz voltage (red) and current (black) are plotted.

During the 50Hz cycle, the power supply is only consuming current at some moments. The behavior typically corresponds to a diode-bridge rectifier with a capacitance stabilizing the DC-voltage. During the period of conduction which can be identified by analyzing the 50Hz current, a higher noise output was seen at the HF-voltage. Next to that, an impulse is noticed in the HF-voltage at the beginning and the end of the conduction period (see figure 2).

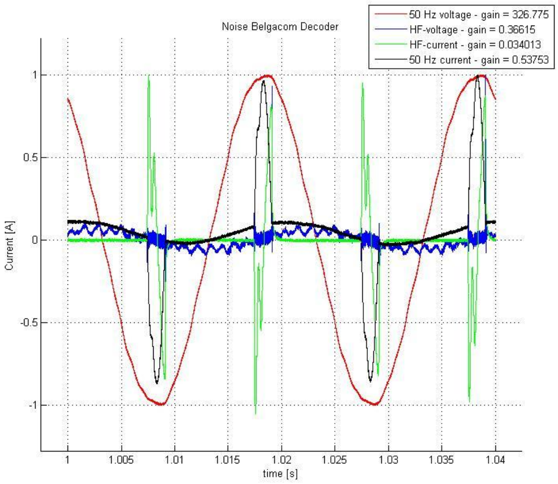

Figure 1: Time domain view for a Digital TV decoder

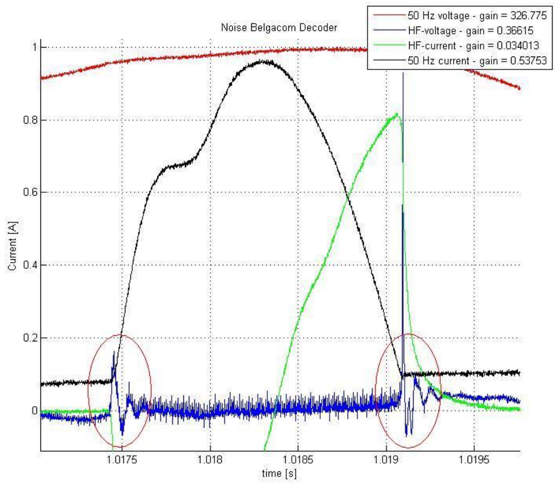

Figure 2: Time domain view for a Digital TV decoder (zoom)

In figure 3, the periodic noise is analyzed. During the periods of conduction in reference to the 50Hz cycle, a significant higher noise level was seen. The HF voltage treatment shows the appearance of impulses, covering the whole frequency spectrum. Typically the impulse at the end of the conduction period is much stronger than the impulse at the beginning of the conduction period.

In figure 4, the stationary noise produced by the Digital TV decoder is depicted. The noise is mostly situated around -100 to -110 db/Hz. This corresponds to the noise level mostly seen outside the periods of conduction. Since the treatment uses a median approach, this is logical because the phenomena during periods of conduction only appear on a very short time in the 50Hz cycle. Around 95kHz, the noise is a bit higher. This also corresponds with the periodic noise.

Finally the periodic impedance is shown in figure 5. Outside the period of conduction, the impedance is rather high, namely in the range of a few tens of kΩ at some frequencies.

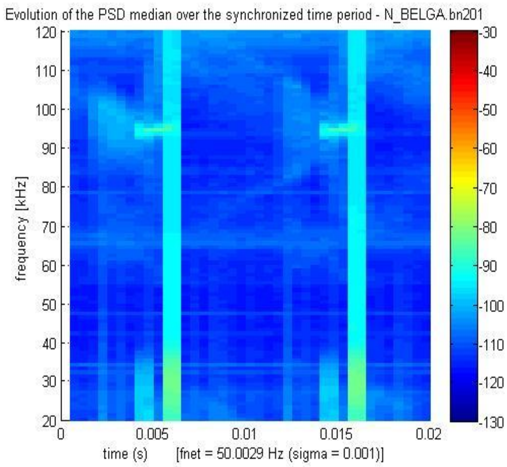

Figure 3: Periodic noise produced by the Digital TV decoder

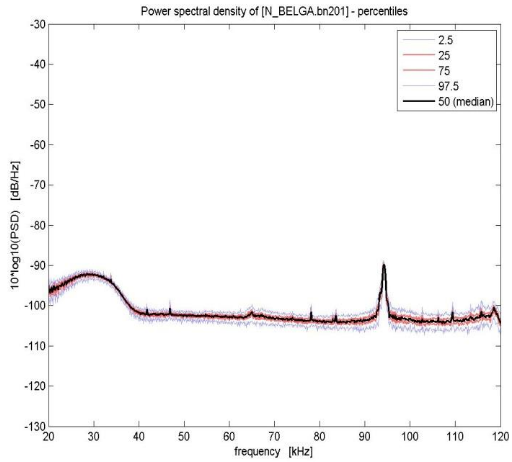

Figure 4: Stationary noise produced by the Digital TV decoder

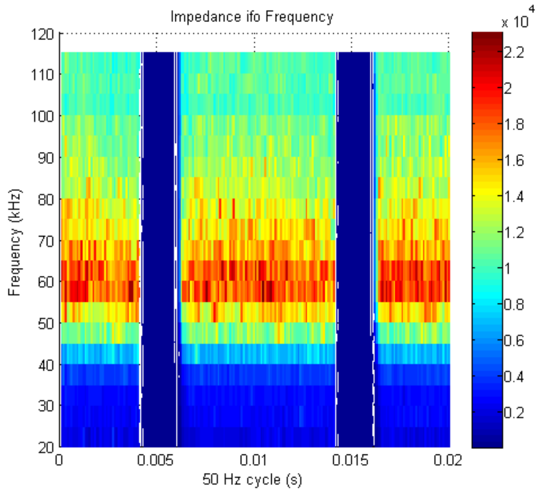

Figure 5: Periodic impedance analysis on the Digital TV decoder

In contrast to that, the impedance drops significantly during periods of conduction, namely to some tens of Ω. It was also seen that the impedance in those zones showed a linear profile, corresponding to an inductance value of 0.8mH.

The measurements of all consumer electronics lead to a classification of the different types of loads in function of the different basic parameters influencing power line communications (figure 6). Note that the Digital TV decoder, investigated above, is characterized by a relatively high input impedance and a medium noise level.

Depending on the type of mains input circuitry and power conditioning, we could distinguish four main categories. The red color on the axis indicates the level of severity of impact on power line communication signaling. Lighting equipment for public and for home lighting was identified as a severe malicious load. The combined effect of a very low input impedance, caused by EMC-filters, and the production of high-level and periodically (20 ms – base) changing noise has the worse impact. The load bench allows us to verify the correct functioning of our measuring device but also gives us the possibility to apply commonly found disturbances in the grid, to PLC modems that are being tested in our lab.

Transfer function

As mentioned before, the PLC toolbox can also be used to measure the transfer function. In some cases this characteristic explains the performance of the propagation of a PLC communication signal.

Measurements in the LV grid showed a very low impedance in the substation, around 1-2Ω. The MV/LV transformer plays a key role in this.

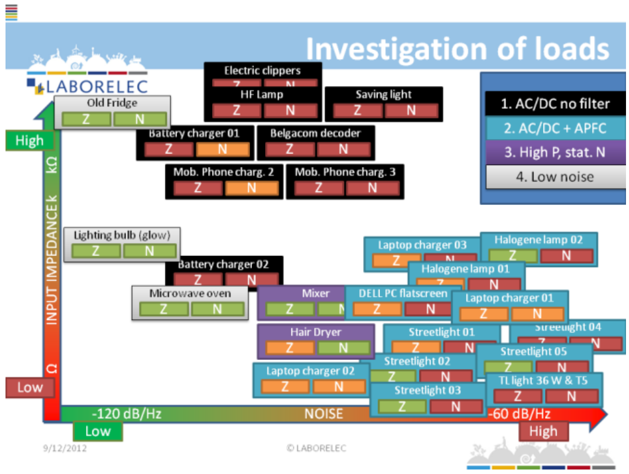

Figure 6: Classification of loads in function of the noise and the input impedance

Measurements are performed of the transfer function of the line between a substation and a customer in Rode – Belgium. In this substation, a filter between the transformer and the main bus bar ensures a high impedance, preventing the PLC signal to disappear through the transformer in the MV-grid. The transfer function was measured in both directions and plotted in figure 7.

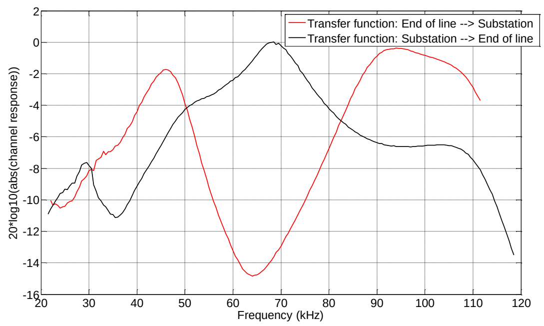

Figure 6: Transfer function from the end of the line to the substation and vice versa

Those measurements are used to explain the poor performance of the PLC signal from the end of the line towards the substation at 65kHz. Around this frequency, the transfer function in that direction shows a dip, which means that the signal is strongly attenuated when propagating from the end of the line to the substation. In the opposite direction, the PLC communication works fine around 65kHz. The signal is hardly attenuated at this frequency. These measurement results are confirmed by the tests conducted with PLC modems communicating in the same frequency band.

CONCLUSION

Analysis done on loads present in the grid shows different categories of polluting charges leading to the possible disturbance of PLC communication.

Furthermore, the low input impedance and high noise of consumer appliances in the CENELEC A-band forms a threat to the use of PLC communication. In this frequency range there is no limitation for disturbances by the standardization bodies. Insights gained in the behavior of common grid elements through fundamental characterization allowed to give feedback to grid operators and manufacturers, assisting them in the right choice of technologies, considering PLC propagation.

ACKNOWLEDGEMENT

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