Interference of LED Lamps on Narrowband Power Line Communication

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Abstract—This paper presents the impact of LED lamps on the performance of Narrowband Power Line Communication (NB-PLC) in the CENELEC-A band between 9-95 kHz. NB-PLC is only one of the many victims of interference in the frequency range 2-150 kHz. Only few emission standards for this frequency range are available, while the number of interference cases is growing rapidly. Most equipment will fail at a specific frequency and/or level. PLC is chosen as a victim, as the performance of the PLC is rated through well-established parameters. One of these is the Frame Error Rate (FER), which is calculated as the ratio between the erroneous frames and total received frames. The number of LED lamps has a strong correlation with the peak amplitude of the current pulses from the LED lamps and the FER of the PLC data frames.

Keywords—Power Line Communication, pulsed current, LED lamps, interference, Frame Error Rate.

I. INTRODUCTION

Smart grid is an emerging technology which enables the electrical power network to be more efficient, flexible and sustainable by controlling the electric power generation, distribution and the consumption over the grid by means of communication. Smart grid technology involves the use of smart meters for measuring and sending the power consumption from the user to the utility provider. Previous research has shown that the correct measurement of power can be influenced by impulsive currents [1], which shows the power line to be an EMI harsh environment. In several countries smart meters have been deployed, that use Power Line Communication (PLC).

PLC technology has gained interest because it offers a low cost solution for the communication inside the smart grid by utilizing the widespread network of the power line, thus no additional transmission line or wireless connection is needed [2]. Only PLC below 150 kHz is considered, as this is a valid way of communication without causing, as far as known, radiated Electro-Magnetic Interference (EMI) problems. PLC above this frequency results in radiated emission and is often a cause of increased Man-Made Noise [3] and is causing EMI issues towards wireless systems.

The increasing use of modern, energy efficient electrical equipment connected to the power lines are causing conducted interference. Especially in the frequency range 2-150 kHz, where there are no sufficient standards for the maximum emission level of these non-linear loads [4], [5]. These type of loads produce periodic impulsive noise which can disrupt the performance of many equipment [3][6] including the PLC. More specifically, It has been shown in [7], [8] that PLC can be interfered by energy-efficient lamps, however it was assumed not to be affecting the Narrow Band PLC (NB-PLC) which works in the CENELEC-A band

between 3-95 kHz. It has been shown that this is one of the victims of the EMI from these non-linear loads [9]. An observation of the influence of a Switched-Mode Power Supply (SMPS) to PLC is described in [10]. Some cases of the malfunction of the PLC also have been reported in several countries by [3] and [6]. These reports also show that some of the available commercial LED lamps have emission levels that exceed the maximum emission limit defined in the EN55015 standard [11]. The non-linear characteristic of the LED lamps creates impulsive currents which can cause errors in the data transmission of the narrowband PLC. LED lamps have been used in this study as for this type of Equipment Under Test (EUT), the energy is converted in light, which can be dissipated easily. The experiment could have been performed by all kinds of other non-linear EUTs, like motor drives, or SMPS, but in these cases the loading is much more difficult. The effect of LED lamps on the PLC channel has been explained in [7]. However, it was concluded that the effect of the specific LED lamps used in their case posed no threat to PLC done in the CENELEC bands at 3 kHz to 150 kHz.

In this paper, the impact of the interference from LED lamps on the NB-PLC is observed and studied. The number of LED lamps was varied from 0 to 32 with incremental steps of 4 to investigate the effect of the current parameters of the LED lamps. The objective of this work is to understand the key mechanisms for interference, and thus to be able to implement novel Electro-Magnetic Compatibility (EMC) measures, like the ones described in [12]. In that work, the concept of time-frequency diversity has been exploited, showing that a fixed limit line over the frequency range for 100% of the time is not needed if one allows dedicated time slots, the so-called green spots. Also the fixed limit line over the frequency range does not always predict the malfunction of devices, as one can be compliant to the standard and assumed immune, but still be interfered [13]. This paper is structured as follows: Section II describes the experimental setup of the measurement, followed by the interference results in Section III and communication impact results in Section IV, and the conclusions in Section V.

II. EXPERIMENTAL SETUP

The communication test of the PLC is performed using two ATPL360-EK PLC modems from Microchip as the transmitter and receiver of the communication data. The PLC modems work in the frequency range between 35-95 kHz. The modulation used for the communication test is 8PSK which gives the lowest frame length. The PLC modems are separated by only 10 meters to minimize the effect of the signal attenuation due to the cable length. A Line Impedance Stabilization Network (LISN) is used for isolating the test

setup from the interference outside of the setup and provide constant impedance during the measurement. Up to 32 LED lamps are used as non-linear loads which produce current pulses as the source of interference. A breakout box is used in combination with a multichannel digitizer to measure voltages and currents simultaneously [14], [15]. A TA189 current clamp from Pico Technology is used for measuring the line current. The multichannel digitizer is a Picoscope 4824. An overview of the measurement setup is shown in Fig. 1.

Fig. 1: Measurement setup.

III. INTERFERENCE TEST RESULT

The LED lamps produce current pulses with a period of 20 ms. The spectrogram is plotted for the current, while the time domain plot of the voltage and current of 32 LED lamps is shown in Fig.2.

Fig. 2: Spectrogram of the current and the time domain plot of the voltage (blue) and current (red) of 32 LED lamps.

The spectrogram and the time domain plot of the PLC data frame are shown in Fig.3. The length of the PLC signal data frame is 17.9 ms and the frequency of the PLC signal is between 35-95 kHz. It is also observed that the current amplitude of the PLC signal is 0.4 A.

Fig. 3: Spectrogram and the time domain plot of the current of the PLC signal.

By processing the resulting data from the short-time FFT, the frequency domain data of the current from the LED lamps can be obtained as shown in Fig.4 and Fig.5. It can be clearly seen that the noise produced by the LED lamps are well below the signal levels of the PLC. Hence it was not expected that the communication would be disturbed, like explained in [7].

Fig. 4: Short-time FFT plot of the current from LED lamps

Fig. 5: Short-time FFT plot of the current from the PLC modem and LED lamps

IV. COMMUNICATION TEST RESULT

The measurement of the impact of the current pulses from the LED lamps to the communication performance of the PLC modem is performed by sending 10000 frames. Each frame contains 10 bytes of data with 17.9 ms duration and 40 ms of mean receiving interval between the previous and next frame. From the communication test results, broken data frames have been observed and calculated to obtain the FER.

The spectrogram and time domain plot in Fig. 5 show the example of a situation where the data frames are hit by the current pulses from 32 LED lamps, which does not directly mean the packet is dropped.

Fig. 6: Spectrogram and the time domain plot of the data frames of the PLC signal which are disturbed by the current pulses from the 32 LED lamps

In Table 1 the effect of the number of LED lamps is summarized. It can be seen with increasing number of lamps the peak amplitude of the current pulses increases significantly.

TABLE I. IMPACT OF LED LAMPS ON PLC

# LED lamps	Peak current (A)	Pulse width (ms)	Broken Frames	Total Received Frames	FER
0	0	0	0	9996	0%
4	0.45	1.7	0	9997	0%
8	0.89	1.8	0	9777	0%
12	1.31	1.89	0	9950	0%
16	1.75	1.82	19	9983	0.19%
20	2.11	1.93	509	9997	5.1%
24	2.5	1.9	437	9997	4.4%
28	2.91	1.96	916	9959	9.2%
32	3.2	2.03	1330	9992	13.3%

The communication test result shows that the frame errors are starting to occur with 16 LED lamps which produce peak currents of 1.75A and pulse width of 1.82 ms. 32 LED lamps produce 13.3% of FER, which is significantly high for data communication. The experiments show that the PLC is being interfered more with an increasing number of LED lamps.

V. CONCLUSIONS

The effect of conducted interference emanating from LED lamps on the performance of narrowband PLC has been evaluated. In this paper it was shown that NB-PLC is vulnerable to the impulsive current interference caused by LED lamps, even though the in band EMI is of a low level. Increasing number of LED lamps are causing more frame drops, with a tested maximum of 32 LED lamps that resulted in almost 13.3% of FER. Further investigation into the mechanism of EMI are required to determine the exact cause of the erroneous frames.

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