The Influence of Fluorescent Lamps with Electronic Ballast on the Low Voltage PLC Network

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***Abstract*—The fluorescent lamps or fluorescent tubes are low pressure mercury-vapor gas-discharge lamps that use fluorescence to produce visible light. These lamps inject noise into the power-line communications channel. This can have a detrimental effect on the power-line communication system. In this paper we investigate the effects when the fluorescent lamps with electronic ballasts are seen as noise sources on the power-line channel. It is shown that in the CENELEC band: (3kHz – 150kHz) the interference level from fluorescent lamps is significantly below the allowed maximum PLC signal levels. In the band 150kHz – 30MHz however, PLC signals compete with Electromagnetic Compatibility (EMC) levels. The operational method of the electronic ballast inside the fluorescent lamp is explained.**

***Index Terms*—** Fluorescent Lamp, Electronic Ballast, Power-line Communications, PLC, Interference, EN 50065-1, EMC.

I. Introduction

The fluorescent lamp is a thermally sensitive light source and the average luminous output from a fluorescent lamp is 75 Lumens/Watt [1]. The lamp wattage characteristic changes with ambient temperature because the changing mercury vapor pressure within the lamp alters the voltage and current values, as well as their associated phase relationships.

Electrical ballast is a device intended to limit the amount of current in an electric circuit and it uses half-bridge inverter and a boost dc-dc converter [2]. A familiar and widely used example is the inductive ballast used in fluorescent lamps, to limit the current through the tube, which would otherwise rise to destructive levels due to the tube's negative resistance characteristic. Fig.1 shows one of the different types of electronic ballasts.

Ballasts vary in design complexity; they can be as simple as a series resistor or inductor, capacitors, or a combination thereof or as complex as electronic ballasts used with fluorescent lamps and high-intensity discharge lamps. The electronic ballasts fluorescent lamps are considered better than the electromagnetic ballasts since they provide a better efficiency (Lumen/Watt), they are smaller and lighter than the electromagnetic counterparts and they prolong the lamp's life [3].

However, fluorescent lamps with electronic ballasts do inject undesired noise into the power-line communications channel.

It is shown that in the CENELEC band: (3kHz – 150kHz) the interference level from the fluorescent lamps is significantly below the allowed maximum PLC signal levels and therefore poses no threat to the power-line communications. In the band 150kHz – 30MHz however, PLC signals compete with Electromagnetic Compatibility (EMC) levels.

This paper investigates the effects when fluorescent lamps with electronic ballasts are seen as interference sources on the wiring system of the powerline communications channel. Two different measurement set-ups (depending on the interference band) are given.

The procedure of the measurements was made to comply with CENELEC narrowband rules in one case, and to serve the broadband signals in the other case [4]. The power-line regulations were considered when performing related measurements.

Fig. 1. Electronic Ballast Used In The Fluorescent Lamp

II. MEASUREMENT SET-UP

The measurement set-up used is shown in Fig.2. A fluorescent lamp is supplied with 220VAC through an isolation transformer and Line Impedance Stabilization Network (LISN). The isolation transformer is used as the LISN causes an earth-leakage current to flow, that trips the supply. Floating the LISN rectifies this fault condition. The LISN as used in this set-up has two functions

- Firstly, it filters noise from the AC supply. The measurement side (current probe and fluorescent lamp in Fig. 2) is therefore clean from any noise on the power-line and an accurate assessment of the noise produced by the fluorescent lamp can therefore be made. A clean 50Hz 220VAC is supplied to the fluorescent lamp.
- Secondly, it supplies a standardized noise load to the conducted interference created by fluorescent lamp. At higher frequencies (typically > 1MHz) the noise load impedance presented by the LISN (and seen by the fluorescent lamp) is 50Ω.

Measurements and conclusions in this paper are made for two regions of the emission spectrum:

- 3kHz – 150kHz: This is the frequency range of the so called *CENELEC* bands as defined by EN 50065-1 [5]. Measurements for these bands were made in the frequency domain to obtain harmonics from the resulted spectral density shape. A Rhode & Schwarz FSH4 Spectrum Analyzer and a CM/DM separator were used. It was assumed that the Common Mode (CM) currents are negligible in this band and that all interference is in Differential Mode (DM) – an assumption also used in EN 50065-1. Results were downloaded to a PC for processing. This is shown in Fig. 2.

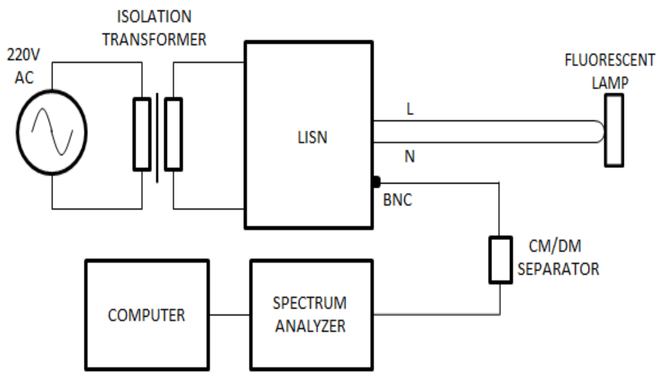

Fig. 2. Measurement set-up for measurements in the 3kHz – 30MHz range.

- 150kHz – 30MHz: This is the frequency range for *Broadband* PLC. It spans the range traditionally used to measure conducted emissions as per CISPR-16 [6]. Measurements for this frequency range were also made using a Rhode & Schwarz FSH4 Spectrum Analyzer and CM/DM separator as shown in Fig. 2.

FLUORESCENT LAMP DRIVER

In this section we show that, for noise generation in fluorescent lamps, there is a common structure of the electronic ballast fluorescent lamp drivers, which consists of different amplifiers and electronic components as shown in Fig. 3.

Fluorescent lamps require a ballast to stabilize the current through the lamp, and to provide the initial striking voltage required to start the arc discharge. Those electronic ballasts employ transistors to change the supply frequency into high-frequency AC while also regulating the current flow in the lamp. Electronic ballasts typically work in rapid start or instant start mode, and are commonly supplied with AC power, which is internally converted to DC and then back to a variable frequency AC waveform.

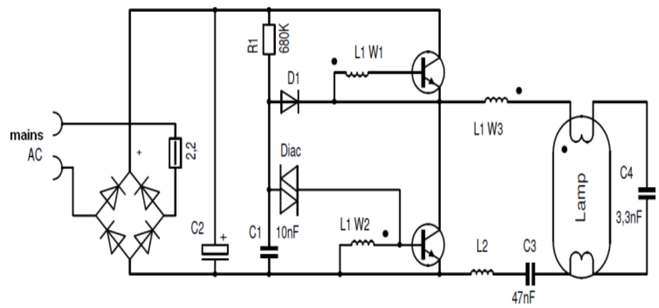

Fig. 3. Electronic ballast fluorescent lamp driver (inverter).

III. HARMONICS - CENELEC BANDS

In order to determine what effect the harmonics of a fluorescent lamp has on the power-line communications channel, a CM/DM-Separator is used in this type of measurements. This is done to subtract the Differential Mode from the Common Mode as stated in [5]. The frequency domain harmonics (magnitude) for the waveforms in Fig. 4 were performed when having a steady-state noise measurement. The steady-state means that the 220V AC is on and the harmonics are continuously shown on the screen of the spectrum analyzer. Another measurement was performed when applying switch on/off to the fluorescent lamp power button. It is the impulsive noise that occurs at a fraction of second (less than 100us). This is also shown in Fig. 4.

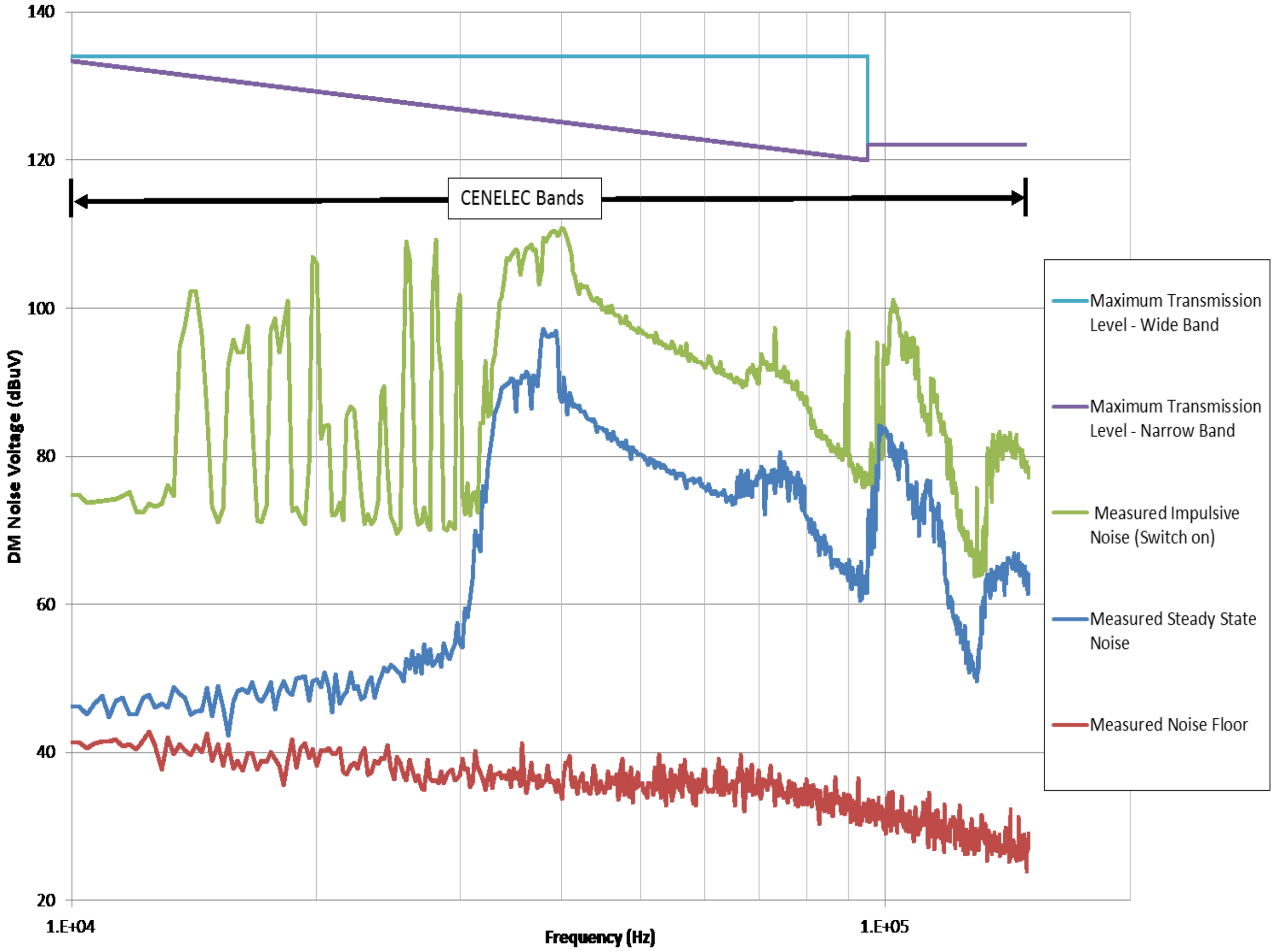

Fig. 4. Frequency domain waveforms and harmonics for 3kHz – 150kHz range.

The obtained harmonics (in voltage) are plotted against the CENELEC EN 50065-1 standards for maximum power-line communications signal and Electromagnetic Compatibility (EMC) levels. At 135dBμV (around 5V) the allowable wideband signal strength for a PLC signal is very high. It is around 20 - 40dB higher than the noise harmonics from the signal of the fluorescent lamp. It can therefore clearly be seen that in the CENELEC bands from 3kHz – 150kHz, fluorescent lamps with electronic ballasts are unlikely to interfere with power-line channel communications.

IV. Broadband Spectrum

For this frequency range, a similar procedure of measurements to those of the CENELEC bands was performed to get the most possible accurate results. In terms of noise in the Broadband PLC spectrum (150kHz – 30MHz) the fluorescent lamps with electronic ballasts generate undesired noise in this part of the spectrum. This is shown in Fig. 5. The obtained frequency domain harmonics in this set of measurements, however, compete with the Electromagnetic levels (EMC).

Fig. 5 shows the interference voltage from the fluorescent lamp versus the EMC average and peak/quasi-peak disturbance level limits in the band 150kHz – 30MHz. In the CENELEC bands from 3kHz – 150kHz there are dedicated maximum signal transmission levels. These do not exist in the 150kHz – 30MHz band and maximum signal transmission is assumed to be at the EMC limit levels. It can be seen in Fig. 5 that the interference voltage of the fluorescent lamp is close to and even exceeds (within experimental limits) the EMC limit in the beginning of the band. This can be expected as the manufacturer will only filter noise to the EMC limit in order to save on manufacturing costs. In stark contrast from the CENELEC bands, PLC signals in the 150kHz – 30MHz band have to directly compete with noise from devices with electronic ballasts and may have a zero S/N ratio at certain frequencies.

V. Discussion And illustration

From a PLC standpoint, the fluorescent lamp with electronic ballast is preferred as it doesn’t cause noise (close to the maximum allowable PLC signal level) in the 3kHz – 150

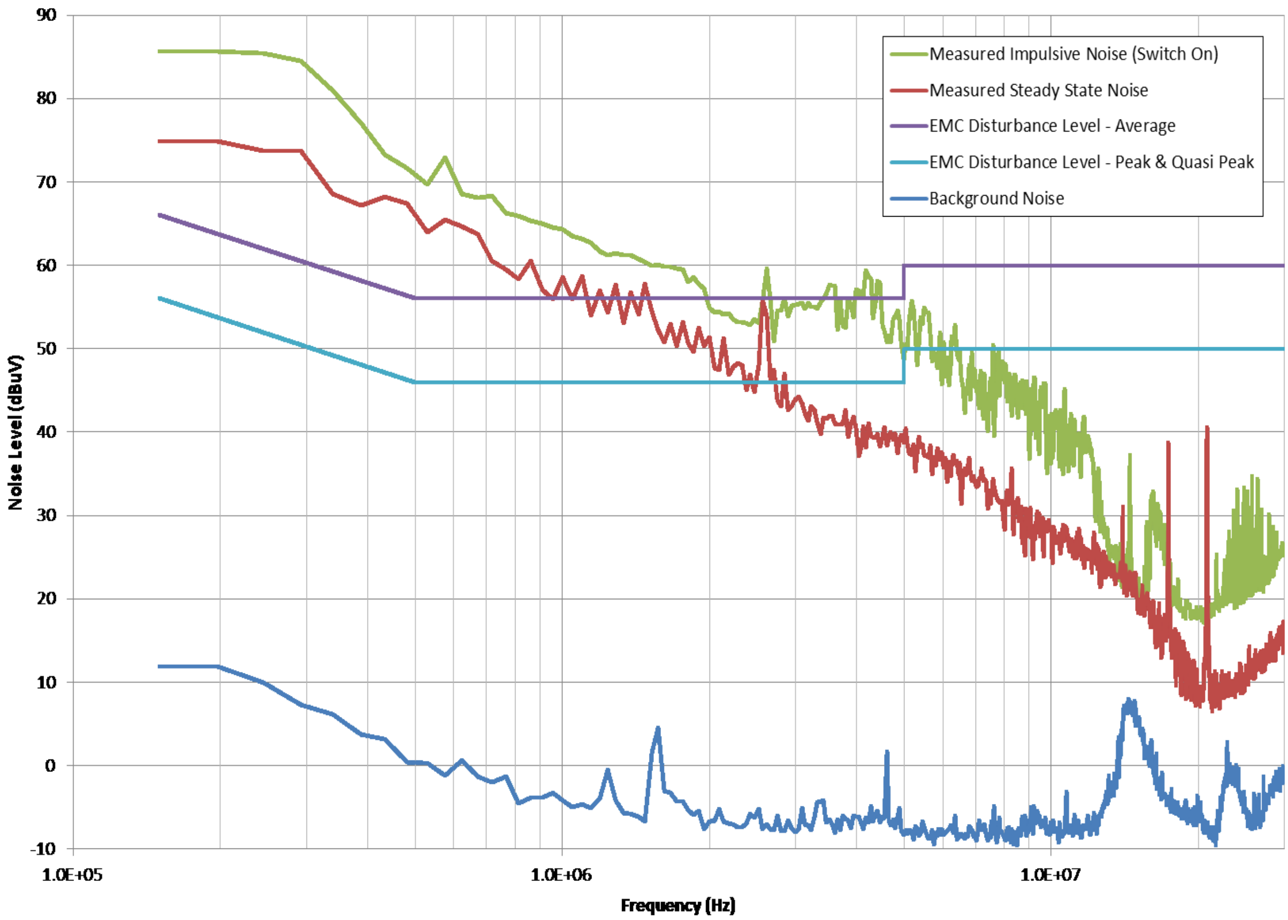

Fig. 5. Frequency domain waveforms and harmonics for 150kHz – 30MHz range.

kHz band. The fluorescent lamps will only become a more favorable lighting solution (in PLC terms) if statuary signal limits are lifted in the 150kHz – 30MHz band. However, by comparing the noise measurements in Fig. 4 to the measured noise floor, we describe the power-line communications channel as an affected channel.

VI. Conclusion

In this paper, details of electronic ballast 36W/220V rms 50Hz for fluorescent lamp are presented. Several measurements have been conducted to illustrate the effects of the fluorescent lamps with electronic ballasts on the power-line communications channel. It has been demonstrated that the fluorescent lamps do inject conductive noise into the PLC channel. Fluorescent lamps produce noise in the 3kHz – 150KHz CENELEC bands, but this interference level is 20dB to 40 dB lower than the allowable PLC signal level and therefore pose no risks for power-line communications. Fluorescent lamps also produce noise in the 150kHz – 30MHz band as the noise level and PLC signal level is governed by EMC standards. Unless this standard is revised and PLC signals allowed to exceed the EMC limit, power-line communication signals will have to compete with zero signal to noise ratios. This is critical as it is envisaged that fluorescent lamps market will move towards other new and different types of lamps as they might be more energy efficient and offer higher functional performance than fluorescent lamps.

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