LED LAMPS IN DIFFERENT EMC ENVIRONMENTS

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ABSTRACT

More and more loads are currently connected at the same connection point in industrial, commercial and residential sectors. This paper studies the interaction between a certain LED lamp connected to different industrial environments, and how different LED lamps behave in the same industrial environment. Harmonic emission as well as supraharmonic emission have been considered in the study.

INTRODUCTION

There are several studies focused on the fact that more and more loads are connected at the same connection point in all sectors of electricity consumers (industrial, commercial, and residential). Individual emission at frequencies up to 2 kHz from devices connected to the grid has been deeply examined. Conducted emission at frequencies between 2 and 150 kHz (also referred to as “supraharmonics” [1]) and the interaction between devices is a less common field of research. It should be appropriate to study any possible interaction between a certain LED lamp connected to different industrial environments, and how different LED lamps behave in the same industrial environment. Both aspects have been discussed in this paper through two LED lamps connected to four different EMC environments.

The concepts primary and secondary emission are not commonly used in studies [2], [3]. Primary emission involves the part of the emission that is propagated from the Equipment Under Test (EUT), while the emission propagated towards the EUT is considered in the secondary emission.

In this paper the primary emission of two LED lamps for different applications (LED for street light, LED for industrial use) has been characterized. In order to do so, the lamps have been connected to a laboratory at Luleå University of Technology in Skellefteå.

This paper also describes how those lamps are affected by highly distorted secondary emissions. For this purpose, the same lamps were connected to three different industrial environments (with a high presence of non-linear loads). The industrial locations are a workshop where trucks are repaired; an industrial factory where hydraulic pistons are manufactured; and an industrial area where an electrolysis process take place.

RESULTS

Two LED lamps for different use have been connected at different locations. The first LED lamp considered is an LED lamp for industrial use, consisting of a matrix of 165 LEDs with 6400 lm. According to the manufacture, the initial input active power is 54 W, and the initial LED luminaire efficacy is 119 Lm/W.

The second lamp considered, is an LED street light consisting of 16 LEDs matrix, with a total luminous flux of 4900 lm. According to the manufacture the power factor is 0.95 and the active power is 43 W.

Low frequency emission

Starting with LED lamp 1, the primary emission in the lab is characterized by an ITHD of 10% (at VTHD 1.88%), an active power of 63 W and DPF of 0.972. As can be seen in the waveform (Fig. 1, left), the current is 430 mA in peak (the smallest amplitude of this lamp among the four locations), and a zero-crossing distortion can also be seen in the current waveform.

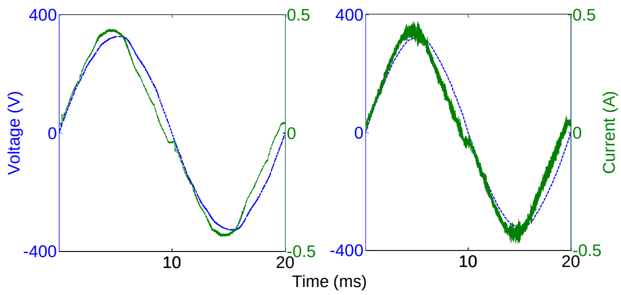

Fig. 1. Voltage and current waveforms from LED lamp 1 in the lab (left) and at site 1 (right).

At site 1 (Fig. 1, right) the measured active power is 61.8 W, with an ITHD of 11% (at VTHD 1.1%), and DPF of 0.986. The peak value of the current is 477 mA and the zero-crossing distortion can be also seen in the current. It is also possible to see a high frequency component in the crest of the current waveform, and overall in the waveform.

At site 2 (Fig. 2, left), the measured active power is 63 W with ITHD 11% (at VTHD 1.69%), and a DPF of 0.967. The current is 480 mA in peak, and the high frequency emission is less than the emission observed at site 1 (Fig. 1, right). The zero-crossing distortion is also visible in the current.

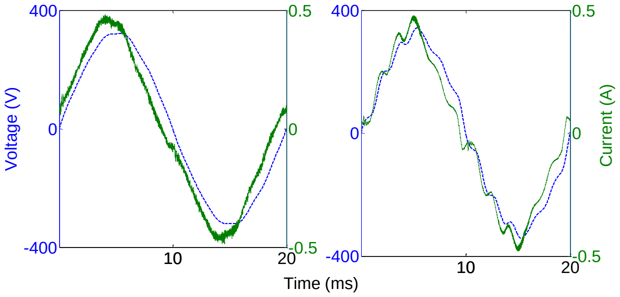

Fig. 2. Voltage and current waveforms from LED lamp 1 at sites 2 (left) and 3 (right).

Finally, at site 3 (Fig. 2, right) the active power is 61.7 W, and ITHD 13.8 % (measured at VTHD 5.9%). The DPF is 0.989 and the peak current is 470 mA. It should be noted that the voltage waveform is heavily distorted compared with the previous sites. This is mainly due to large 6 pulse rectifier loads connected in the facility. At this site, the current waveform follows a different shape and appears to have higher low frequency secondary emission.

Next to that, the second LED lamp was connected to the same four locations. In the case when the LED lamp is measured in the lab (Fig. 3, left), the active power is 56 W with an THDI of 11.3% (at VTHD 2%), the DPF is 0.966 and the peak current reaches 385 mA. Similar as the first lamp, it is possible to see waveform distortion in the current around the voltage zero crossing.

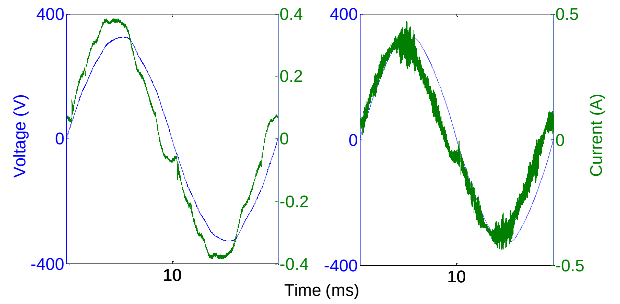

Fig. 3. Voltage and current waveforms from LED lamp 2 in the lab (left) and at site 1 (right).

The presence of secondary emission is higher at site 1 (Fig. 3, right) compared with the measurements in the lab, which was also the case with the first LED lamp at site 1. Some measured data are an active power of 56 W, with ITHD 11.4% (at VTHD 1.2% FND), and the DPF is 0.963. The peak in the current reaches 470 mA, which is higher than the peak reached in the lab. This is mainly due to higher frequency distortion at the peak of the current waveform.

At site 2 (Fig. 4, left) the secondary emission is also visible but mainly at the peaks of the currents. Note that the emission appears to be less than at site 1. The peak current reaches 423 mA. Some measured data are an active power of 57.7 W, measured with a THDI of 11.2 %FND (at VTHD 1.56 %FND), and a DPF of 0.937.

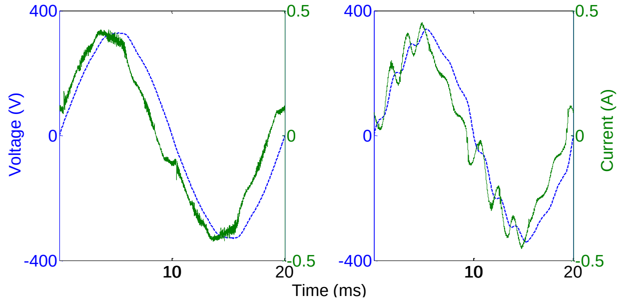

Fig. 4. Voltage and current waveforms from LED lamp 2 at sites 2 (left) and 3 (right).

Finally, at site 3 (Fig. 4, right) the waveform of the current is similar to the one seen in the first lamp at the same location, mainly due to the 6 pulse rectifier loads, and with a 453 mA peak current. Some measured data are an active power of 55.8 W, measured with ITHD 18.4 % (at VTHD 5.9%), and a DPF of 0.9698.

A summary of some power quality parameters for both LED lamps is given in Table 1 and 2. It can be seen that a similar voltage distortion as in the first three locations also result in a similar current distortion. However, at site 3 the ITHD is almost 3% and 7% (for lamps 1 and 2 respectively) higher compared with the other locations due to higher voltage distortion.

Table 1. Power Quality parameters for LED lamp 1

	Lab	Site 1	Site 2	Site 3
ITHD (2kHz) (%FND)	10	11	11	13.8
VTHD (2kHz) (%FND)	1.88	1.1	1.69	5.9
P (W)	63	61.8	63	61.7
FND (mA)	281	273	288	277

Table 2. Power Quality parameters for LED lamp 2

	Lab	Site 1	Site 2	Site 3
ITHD (2kHz) (%FND)	11.3	11.4	11.2	18.4
VTHD (2kHz) (%FND)	2	1.2	1.56	5.9
P (W)	56	56	57.7	55.8
FND (mA)	252	252	269	256

Next figures show harmonic distortion (up to 2 kHz) from both lamps at four locations. Both voltage (Fig. 5) and current (Fig. 6) harmonics are considered. These frequency components have been grouped according to harmonic groups in IEC 61000-4-7 [4]. Every individual lamp at every location was measured during several hours, and a small variation in the emission has been observed within this period. In order to show this evolution, the variation of the values over the measured period is shown in a way that the height of the bar represents the average over the period, while the lines on top of the bar show 10 (lower horizontal line) and 90 (upper horizontal line) percentiles values over the period.

In the case of voltage harmonics, a similar spectrum can be seen in both lamps, therefore both lamps are subjected to the same voltage distortion and a comparison between them is then possible. As it was also expected, the impedances of the lamps are not big enough to impact the voltage after their connections.

In the analysis of the variation over the period, it can be seen that some orders vary more than others do (5th voltage harmonic varies much at site 2 compared with the measurement in the lab); however, overall site 3 has higher variation over the period, equally affecting both lamps. On the other hand, lab measurement shows the lowest variation over the period.

Regarding amplitudes, although site 3 has the highest amplitudes from harmonics 5 to 15, other orders reach the highest voltage amplitude at different locations. For example, 3rd harmonic has higher amplitude at site 2 (around 2 Vrms in both lamps).

At site 3, order 11 has the highest amplitude (9.5 Vrms in average for both lamps) followed by 5th, 13th and 7th harmonics which have an amplitude around 5 Vrms. In contrast, the other three locations have values around 1 Vrms or even reaching a maximum of 3 Vrms in the case of order 5 in the lab.

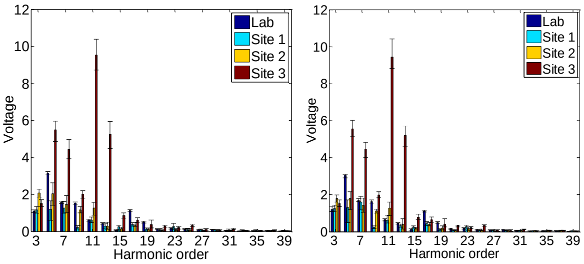

Fig. 5. Harmonic voltage spectrum for LED lamp 1(left) and lamp 2 (right).

In the case of current harmonics, the similarities between lamps and locations are not as noticeable as in the voltage. In spite of this comment, both lamps follow the same decreasing tendency, and as an example, they both have higher values of 3rd harmonic (although higher for the LED lamp 1 –around 30 mA than for lamp 2 – around 25 mA).

As in the voltage, site 3 has higher values in 7th, 11th, 13th and 15th compared to other locations (in lamp 1, harmonic 11 has 19 mA at site 3 compared with 1.63 mA at site 1). Particularly low is the value of harmonic 5 in the lab for lamp 1 (0.3 mA). In lamp 2, 11th harmonic reaches the highest amplitude (even above order 3).

Higher orders (up to 39) have similar values at all locations.

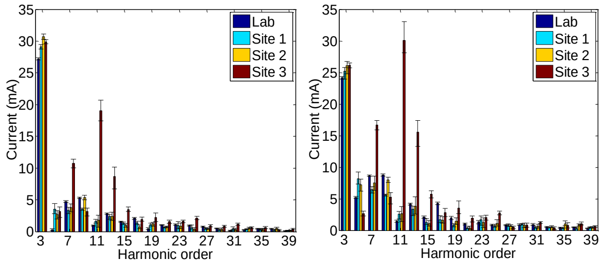

Fig. 6. Harmonic current spectrum for LED lamp 1(left) and lamp 2 (right).

Supraharmonic emission

Not only has the harmonic range been considered. Also the supraharmonic range will be discussed. Next figures show the harmonic spectrum within the high frequency range (from 2 to 150 kHz). These frequency components have been grouped according to Annex B in IEC 61000-4-7 [4]. Again, the evolution of the values over the measured period has been shown. Also in this case the height of the bar represents the average over the period, while the lines on top of the bar show 10 and 90 percentiles values over the period.

In the lab (Fig. 7), an overall broadband emission is observed for both lamps. In lamp 1, the maximum amplitude is reached at 3.8 kHz (varying from 0.936-1.072 mA). There is also a peak at 32.4 kHz (0.14-0.17 mA). Then, the emission from 42-60 kHz (amplitude varying from 0.16-0.34 mA) corresponds to the switching frequency of the PFC circuit of the lamp and it is seen in the spectrogram as an arc like signal [5].

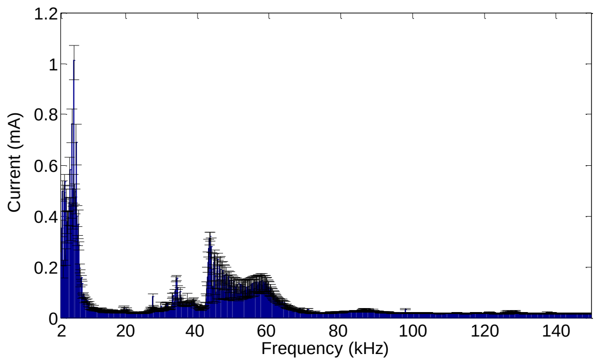

Fig. 7. The 200-Hz band spectrum of the current feeding the LED lamp 1 in the lab (2-150 kHz).

In lamp 2 (Fig. 8) the broadband emission is observed in the range 17-30 kHz. The constant value seeing at 21.6 kHz has 1.84 mA amplitude, higher than the value at 2 kHz (1 mA). The other constant value at 64 kHz is 0.123 mA, higher compared to the amplitudes from the side frequencies (0.026 mA). Those peak values are expected to be secondary emission, although more research is needed.

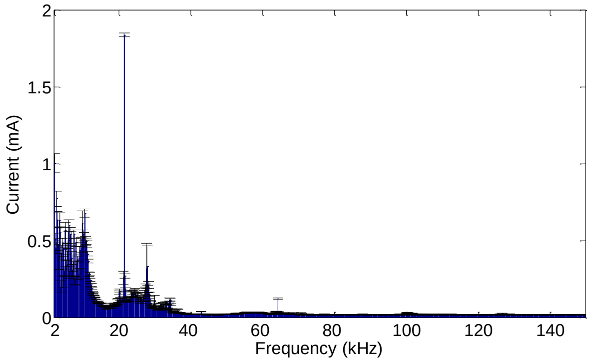

Fig. 8. The 200-Hz band spectrum of the current feeding the LED lamp 2 in the lab (2-150 kHz).

Next to that, at site 1 there is a broadband emission from 30-80 kHz seen with both lamps, so it is basically secondary emission. In the case of LED lamp 1 the emission has a peak at 34.8 kHz (reaching 2.5 mA), and then the amplitude decreases up to 0.6 mA. In the frequency range from 2-7 kHz the current reaches a maximum of 0.6 mA.

On the other hand, LED 2 has higher amplitude in the first part of the band 30-80 kHz and at 34.8 kHz the amplitude reaches 5 mA. Then, the amplitude within this band also decreases down to 0.7 mA.

The rather constant value at 19.2 kHz reaches 3.44 mA with LED 1 (90 percentile), 11.67 mA with the LED 2 (90 percentile), reaching the highest amplitude within this supraharmonic range for both lamps. As far as it can be seen in both lamps, this frequency component is due to other loads in the same facility (secondary emission). Another test, not shown here, was done by connecting a capacitor and it also draw the equal 19.2 kHz current.

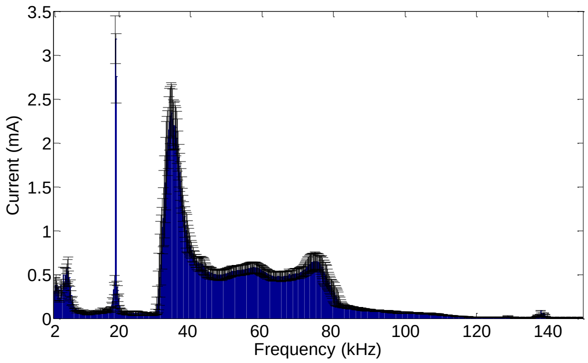

Fig. 9. The 200-Hz band spectrum of the current feeding the LED lamp 1 at site 1 (2-150 kHz).

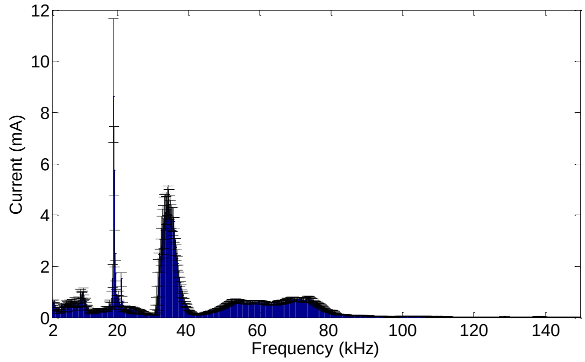

Fig. 10. The 200-Hz band spectrum of the current feeding the LED lamp 2 at site 1 (2-150 kHz).

Site 2 shows the biggest variation within the measured period, and it is basically secondary emission. In lamp 1 there is a broadband emission in the range 42-120 kHz varying significantly over the period (from 0.3-percentile 10- to 2 mA-percentile 90-). In fact, the maximum amplitude is reached within this frequency range and not within lower supraharmonic frequencies (around 0.8 mA at 5.8 kHz compared to 2.1 mA at 106 kHz).

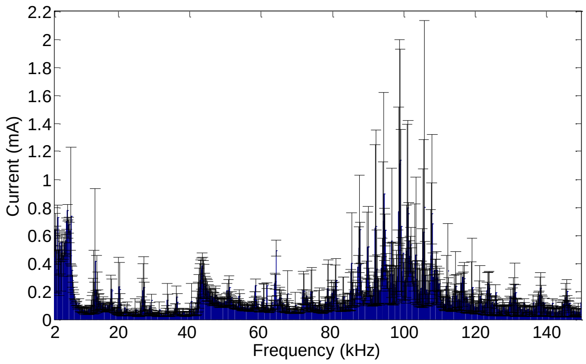

Fig. 11. The 200-Hz band spectrum of the current feeding the LED lamp 1 at site 2 (2-150 kHz).

Regarding lamp 2, the broadband emission takes place at a reduced frequency range (from 60-110 kHz), and the variation within this range for this lamp is not as significant as in the previous lamp (from 0.3-percentile 10- to 0.8 mA-percentile90-). In fact, there is a peak current at 27 kHz showing the biggest variation within the measured period (from 0.52 mA-10 percentile- to 3.07 mA -90 percentile).

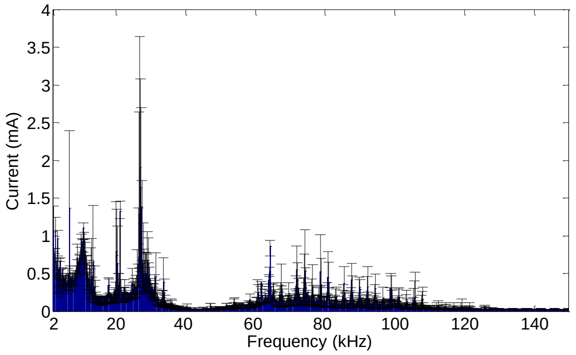

Fig. 12. The 200-Hz band spectrum of the current feeding the LED lamp 2 at site 2 (2-150 kHz).

At site 3, there is also some variation over the measured period, although less than at site 2. As it was previously mentioned when describing the voltage and current waveforms (Fig. 2 and 4 right), in this factory there are 6 pulse converters that are generating peaks at this frequency range and this is the reason for this variation. The emission between lamps is not quite similar. While lamp 1 shows a broadband spectrum in the range 35-80 kHz, lamp 2 is characterized by the range 2-40 kHz. LED lamp 1 reaches the maximum amplitude at 6 kHz (0.91 mA -90 percentile).

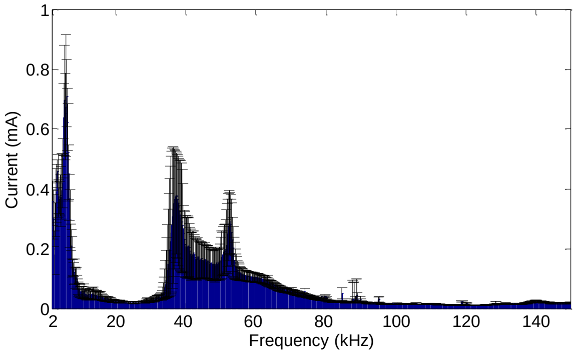

Fig. 13. The 200-Hz band spectrum of the current feeding the LED lamp 1 at site 3 (2-150 kHz).

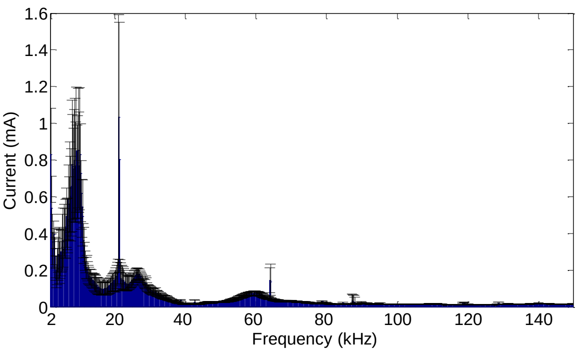

Fig. 14. The 200-Hz band spectrum of the current feeding the LED lamp 2 at site 3 (2-150 kHz).

On the other hand, lamp 2 also presents a peak at 7 kHz (1.2 mA). The same value at 21.6 kHz seen in the lab with this lamp also appears at site 3. The amplitude reached by the peak is also the maximum amplitude reached within this range (1.6 mA).

CONCLUSION

The outcome of the paper is the impact on the secondary emission of a group of LED lamps when they are exposed to different EMC environments. The same background distortion affects in a different way to different lamps. It should be noted that the secondary emission is different at different places, and this might affect the lamps differently. As an example, in [6] was reported a number of equipment figuring as an EMI victim, such as touch-dimmer-lamps, and smart meters with PLC data transmission (AMR-PLC) among others.

Also, the strong point of the paper is that not many research has been done at this moment at industrial environment, moreover using real measurements.

Some industries present bigger variation in amplitude compared to others, that means, loads are subjected to bigger changes.

The same lamp at different locations presents different emission both in the harmonic as well as in the supraharmonic range. But also the same location influences in different way to different loads.

Acknowledgments

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