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Harmonic analysis of a LED luminaire for street lighting, fed by different drivers

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Abstract/Zusammenfassung

The current paper presents an investigation on the harmonic pollution to the grid, introduced by LED street luminaires fed by drivers with different power. The current waveform, the total harmonic distortion and the odd-order harmonics introduced in the power grid by the different luminaire-driver configurations are measured and analysed.

Index Terms: Total harmonic distortion of lighting equipment, LED street lighting, non-linear electric load

1 Introduction/Einleitung

The harmonic distortion and the impact of the non linear loads to the power quality of the electrical grid is a persisting problem, which can lead to significant problems like power factor reduction, unproper function of different protective electrical equipment, interference with circuits for communication etc. [1]. Because of this problem the Standard IEC 61000-3-2:2018/AMD2:2024 [2] sets the limits of the odd-order harmonics and the acceptable THD for equipment with current under 16 A per phase. In this standard the lighting equipment is classified separately into Class C and the harmonic limits, set by it are given in table 1.

Table 1 Harmonic limits for lighting equipment [2]

Harmonic order	Maximum value in % from the input current of luminaire
3	30*λ (λ - power factor of the circuit)
5	10
7	7
9	5

The LED luminaires, especially those used for street and industrial lighting, because of their specificity as an electric load often lead to unwanted effects on the power

quality of the mains. A lot of effort is being made for avoiding this problem, including different control strategies, but it still exists and should not be underestimated.

2 LED luminaire harmionics measurement

An investigation of the electrical power quantities, characterizing the operation of a LED luminaire, powered by different LED drivers (with different power, supplied to the luminaire) is carried out – Fig. 1.

Fig. 1. LED street luminaire and drivers under investigation

For the harmonics measurement procedure a Portable Power Quality Analyzer – CIRCUTOR - Fig. 2 is used and for each driver and operation regime, a five minutes record of the current harmonics and power quantities is taken.

Fig. 2 Measuring device - Portable Power Quality Analyzer – CIRCUTOR

3 Experimental results and Analysis

Because of the significant volume of the measurement data, only some of the results are shown in the paper. Figures 3 to 15.

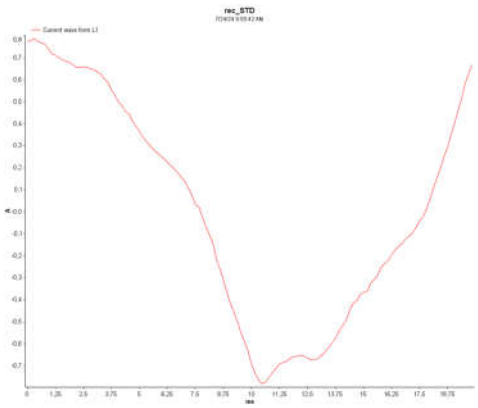

Fig. 3 Current waveform, 1000 mA supply current

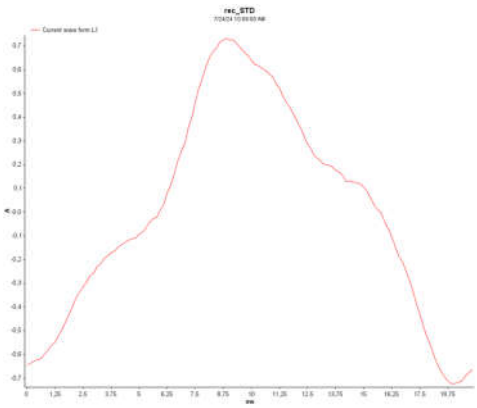

Fig. 4 Current waveform, 950 mA supply current

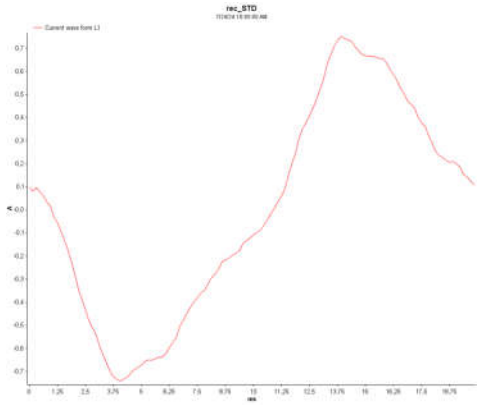

Fig. 5 Current waveform, 900 mA supply current

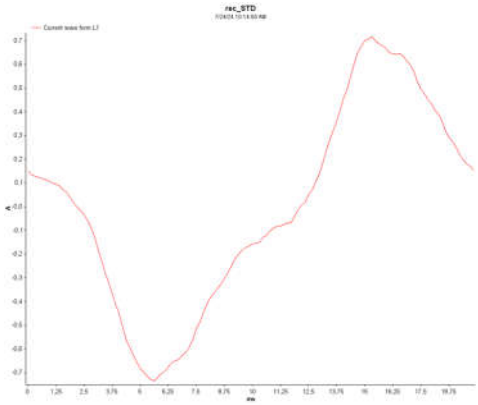

Fig. 6 Current waveform, 850 mA supply current

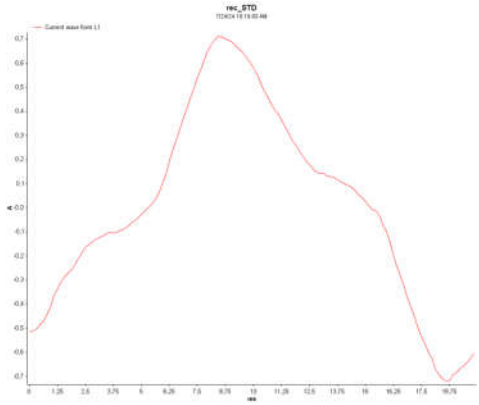

Fig. 7 Current waveform, 800 mA supply current

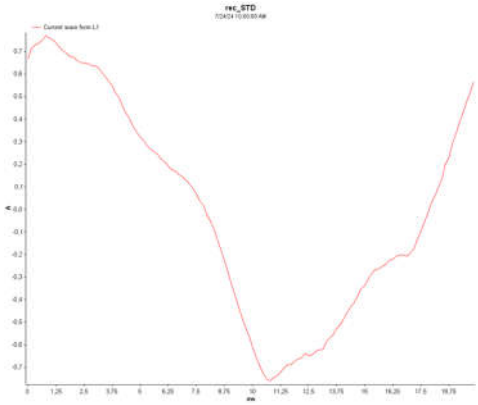

Fig. 8 Current waveform, 750 mA supply current

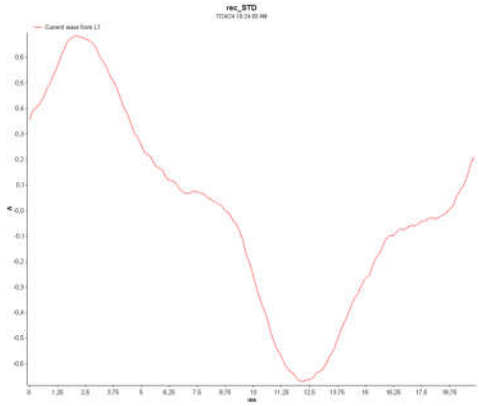

Fig. 9 Current waveform, 700 mA supply current

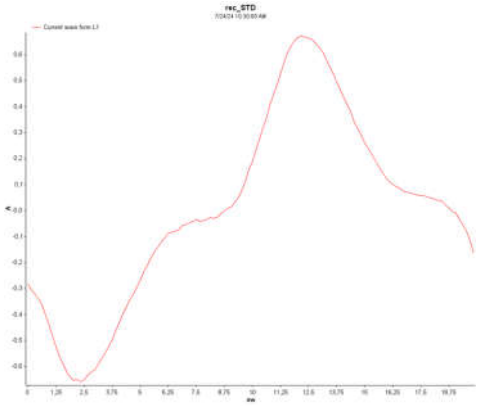

Fig. 10 Current waveform, 650 mA supply current

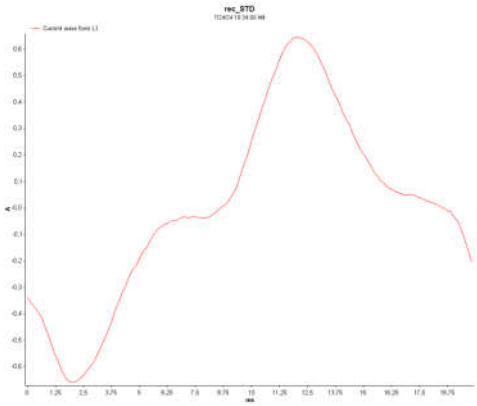

Fig. 11 Current waveform, 600 mA supply current

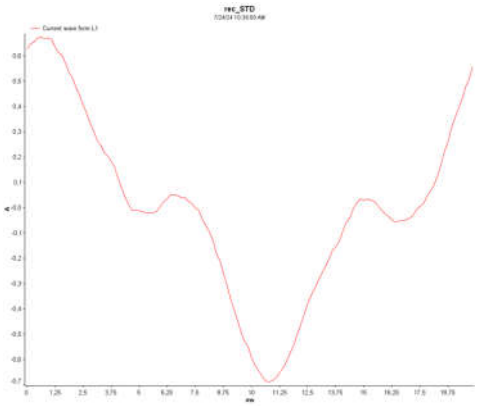

Fig. 12 Current waveform, 550 mA supply current

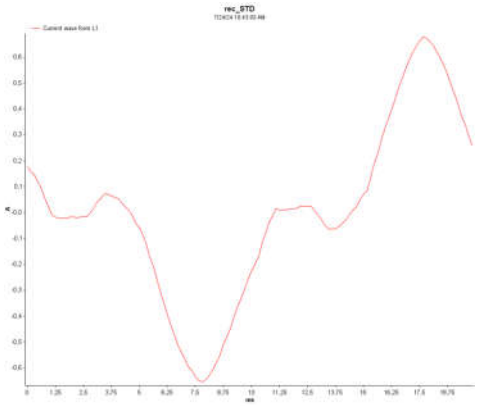

Fig. 13 Current waveform, 500 mA supply current

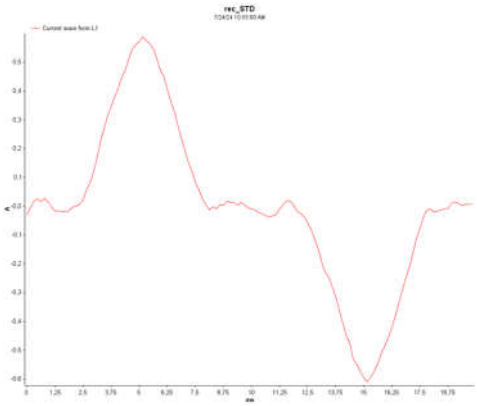

Fig. 14 Current waveform, 450mA supply current

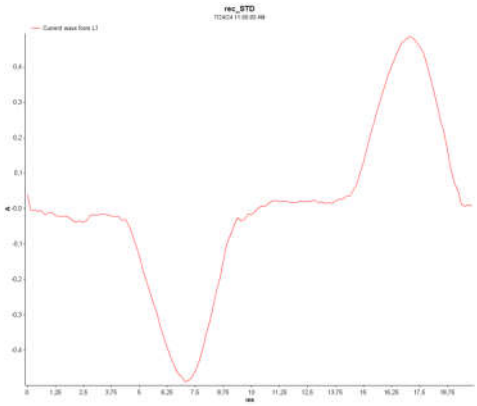

Fig. 15 Current waveform, 400mA supply current

As it is seen from the figures, with the reduction of the supply current fed to the luminaire, the waveform distorts and resembles unlinear load, which is an unwanted effect. The values of the odd-order harmonicas and the total harmonic distortion (THD)

also increase significantly. The Values of the harmonics and THD for each supply current are summarized in table 2.

Table 2 THD and odd-order harmonics generated by the driver-luminaire combination at different supply current levels

Supply current I, mA	**1000**	**950**	**900**	**850**	**800**	**750**	**700**	**650**	**600**	**550**	**500**	**400**	**350**
THD, %	16.3	17.6	20	22.4	24.6	26.8	29.7	32.2	34.5	42	46.2	52	53.9
Harmonic 3, %	14.5	16.5	19.5	22.4	25.4	27.6	30.8	33.7	36.5	46.1	52	59.1	60.1
Harmonic 5, %	7.5	6.3	5.2	4.5	3.9	3.4	3.7	4.2	4.5	3.2	2.8	14.6	21.8
Harmonic 7, %	2.4	3.1	2.3	2						2.6		3.5	
Harmonic 9, %		1.2											3.2

Referring to table 1 it can be noticed that the 3rd order harmonic becomes greater than the acceptable limit when the supply current is lower than 750mA, the 5th order harmonic exceeds the limit set, when the supply current gets lower than 500mA. The 7th order harmonic is always within the limits and the 9th order harmonic is bigger than the limit value for supply currents under 450mA. The THD increases significantly with the decrease of the supply current.

4 Conclusions

The paper presented investigates the harmonic distortion of LED street lighting equipment. It reveals some onfield measurement results, taken for different driver luminaire combinations. The investigated luminaire is only one and the drivers are six, supplying the luminaire with different imput current levels. Evaluation of harmonics generated for the different driver – luminaire combinations is conducted by means of a a power quality analyzer. By the results obtained, it is obvious that some of the values of the odd order harmonics exceed the limits given in IEC61000-3-2 Standard, which means that before the use of a chosen driver-luminaire combination, measurements of the harmonics, generated should be considered and the acceptable dimming levels (minimum supply current) should be additionally predecided, so that no mains disturbance is caused. The maximum total harmonic current should be kept under the limits set, so that the power quality is not discriminated.

5 References

[1] C. Jettanasen, and C. Pothisarn “Analytical Study of Harmonics Issued from LED Lamp Driver”, in Proceedings of the International MultiConference of Engineers and Computer Scientists 2014, Vol. II, IMECS 2014, Hong Kong , March 12 - 14, 2014

[2] IEC 61000-3-2:2018/AMD2:2024 - Amendment 2 - Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤ 16 A per phase).

[3] R. Kalle, A. Hilden, J. Rekola “The impact of led lighting systems to the power quality and recommendations for installation methods to achieve the expected energy efficiency” 25th International Conference on Electricity Distribution, CIRED 2019.

[4] A. Akila, K. Youssef, I. Yassin. Harmonics Monitoring Survey on LED Lamps. Renewable Energy and Sustainable Development. 3. 39-45. 10.21622/resd.2017.03.1.039, 2017.