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Comparative Analysis of Power Quality Indices for Different Lighting Techniogies in Public Lightning

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ABSTRACT

As with any other product, having electricity of a certain quality is very important for consumers. Its quality has become the key feature that can be disturbed by loads based on power electronic devices. Electricity producers are striving to provide reliable and quality electricity supply to consumers. Public lighting systems that are based on LED lighting technology can potentially positively or negatively affect the power quality because they contain power electronics components in LED drivers. Because of that, two 7-day measurements were conducted on the same public lighting branch but with different lighting technologies (high pressure sodium, known as HPS and LED technology). Results of the measurements were analysed and compared. By analysing the results, other problems were also identified by using LED lighting technology. These problems are addressed in the conclusion of the paper.

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1. INTRODUCTION

In the recent period, electricity has started to be considered a product as any other, and its quality has become a very important feature for its consumers. A major problem in power quality is created by consumers based on power electronic devices because they draw non-linear current, which results in voltage distortion generation. The first step in solving this problem is measuring and analysing power quality. Power quality standard EN 50160 gives quantitative requirements for voltage in normal conditions. Its purpose is to describe voltage characteristics in terms of [1]: frequency, waveform, symmetry, magnitude.

Measurement of power quality according to the standard EN 50160 requires specialized instruments and measuring methods which enables continuous monitoring of the following parameters [2], [3], frequency, supply voltage. total harmonic distortion. supply voltage unbalance, flickers, mains signalling voltage. In [3] is presented a technical and economic study of the solar powered street lighting system of a municipality in the south of Morocco. The state of the conventional street lighting system is compared with PV-based lighting.

Power quality parameters, statistical evaluation and compliance limits are given in some papers such as [4]. The voltage flickers as voltage quality problem in industrial sector are presented in [5]. The use of high brightness LEDs has become increasingly accepted as light sources in mainstream vehicles and is presented in [6].

2. POWER QUALITY INDICES

Power quality parameters, statistical evaluation and compliance limits are given in below in Table 1

Table 1. Supply voltage parameters according to EN 50160

Supply voltage parameter	Statistical levels	Compliance limit
Power frequency	95 % of the time in 1 week	50 Hz ± 1 %
	100 % of the time in 1 week	50 Hz + 4 % to - 6 %
Supply voltage variations	Supply voltage variations	95 % of the time in 1 week
Flickers	95 % of the time in 1 week	≤ 1
Supply voltage unbalance	95 % of the time in 1 week	< 2 %
Individual harmonic voltages	95 % of the time in 1 week	See Table 2
Total harmonic distortion	95 % of the time in 1 week	< 8 %
Mains signalling voltage	95 % of the time in 1 week	See Figure 1

Maximal values of odd individual harmonics in percent of nominal voltage are shown in Table 2.

Table 2. Values of individual harmonic voltages according to EN 50160

Odd harmonics not multiples of 3		Odd harmonics multiples of 3	
Order	U_h in % of U_n	Order	U_h in % of U_n
5	6.0	3	5.0
7	5.0	9	1.5
11	3.5	15	0.5
13	3.0	21	0.5
17	2.0		
19	1.5		
23	1.5		
25	1.5		

Also, the presence of mains signalling voltages was recorded in power quality measurements because the Croatian national energy company manages the public lighting system through the power line communication method. Due to this, there are limitations on voltage levels of signal frequencies in percent of U_c used in public low voltage distribution networks.

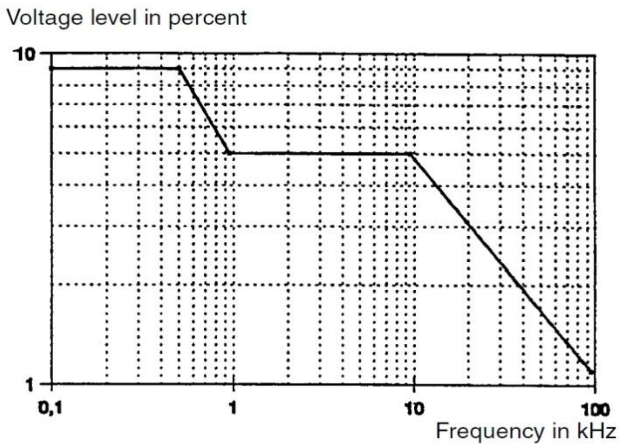

Figure 1. Voltage levels of signal frequencies in low voltage networks

3. MEASUREMENT OF POWER QUALITY ON PUBLIC LIGHTING BRANCH

Measurements are conducted according to the standard EN 50160 with class A measuring device in 7 days' period. The measuring device is a universal tool for power quality analysis and detection of disorder in low and medium voltage distribution network. Specifications of class A three phase power quality measuring device are shown in Table 3 below.

Table 3. Specification of measuring device

IEC 61000-4-30 compliance	Class A
Voltage	•
Current	•
Frequency	•
Dips and swells	•
Harmonics	•
Power and energy	•
Energy loss calculator	•
Unbalance	•
Inrush	•
Power wave	•
Flicker	•
Transients	•
Mains signalling	•
Power inverter efficiency	•

Measurement of power quality is conducted in the same public lighting cabinet on the same branch for both technologies; LED and HPS. Measurements were conducted over a 7-day period, and the figure below shows the point of measurement in relation to the transformer station as shown in Figure 2.

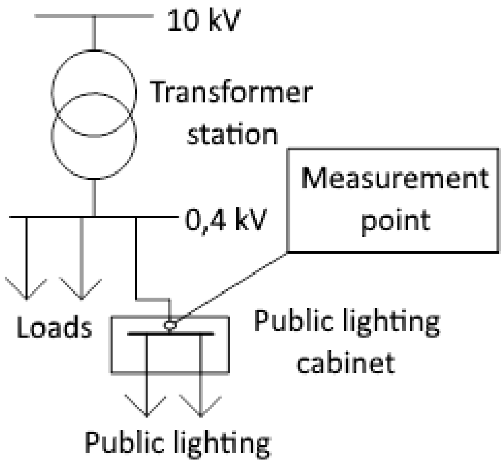

Figure 2. Measurement point in relation with transformer station

Loads and measurement periods for both cases High Pressure Sodium (HPS) and Ligh-Emitting Diode (LED) technology are shown in Table 4.

Table 4. Loads and measurement periods for HPS and LED technology

Lighting technology	Number of lamps	Lamp power [W]	Total lamp power [W]	Measurement period
HPS	10	189	1,890	February 2017 – 14 February 2017
LED	10	17	170	10 March 2017 – 17 March 2017

4. RESULTS OF POWER QUALITY MEASUREMENTS ON PUBLIC LIGHTING BRANCH

Summarized results of power quality measurements in public lighting for two cases (HPS and LED technology) are shown in the table below. Table 5 shows that all power quality parameters are satisfied and are consistent with standard EN 50160.

Table 5. Table 4. Loads and measurement periods for HPS and LED technology

Power quality parameter	HPS technology	LED technology
Frequency	OK	OK
Voltage	OK	OK
Flicker	OK	OK
THD	OK	OK
Unbalance	OK	OK
Mains signalling	OK	OK

As is mentioned in the previous chapter, measurements of power quality for both HPS and LED technology show that all power quality parameters are satisfied and fully compliant with the standard EN 50160. Analysis and comparison of measurement results for each parameter that has changed by changing the lighting technology is given below. Total harmonic distortion of supply voltage is below the level prescribed by the standard EN 50160 (8 %), but generally THD in the absolute amount for case of LED is higher by approximately 0.25 % compared with HPS, as shown in Figure 3 and Figure 4.

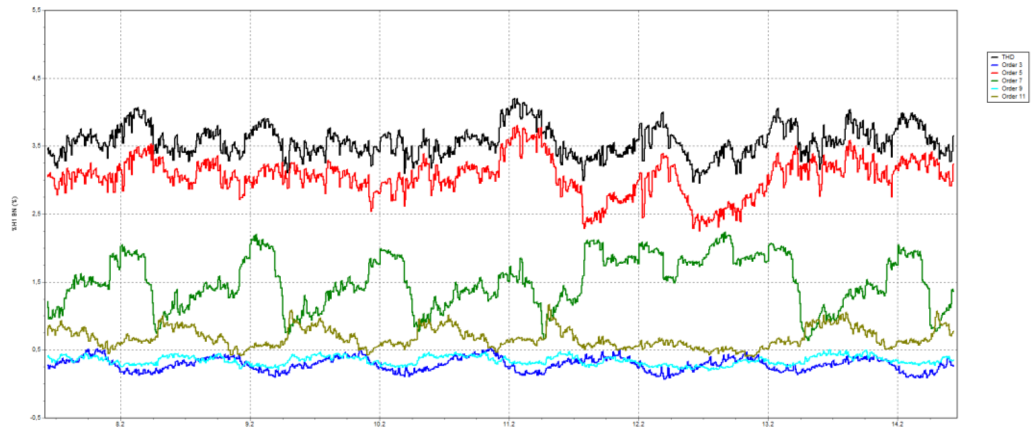

Figure 3. Total harmonic distortion of supply voltage – HPS

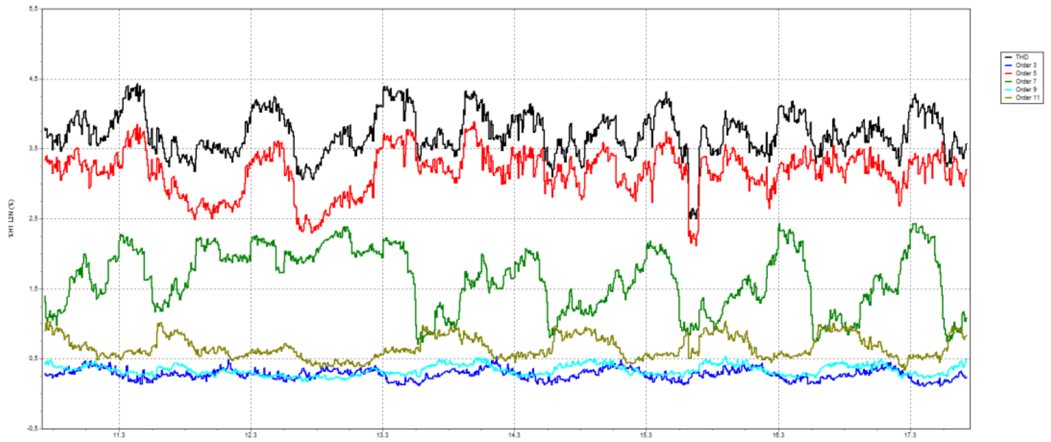

Figure 4. Total harmonic distortion of supply voltage – LED

Also, in terms of rapid voltage changes, long term flicker severity caused by voltage fluctuations is below the level prescribed by the Standard. In comparison with LED, HPS technology is more stable due to there are no so many peaks as in LED technology. Although the mean values of long term flickers are approximately equal, HPS has no significant deviations from the overall weekly trend (Figure 5 and Figure 6).

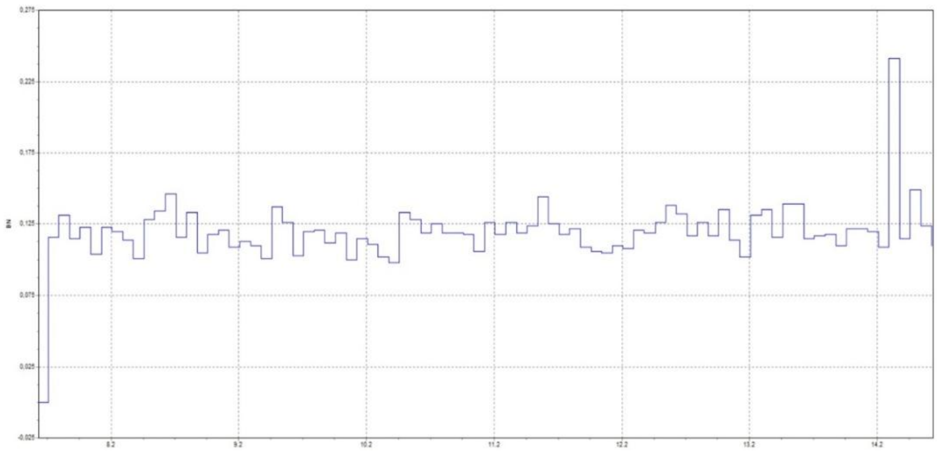

Figure 5. Long term flicker – HPS

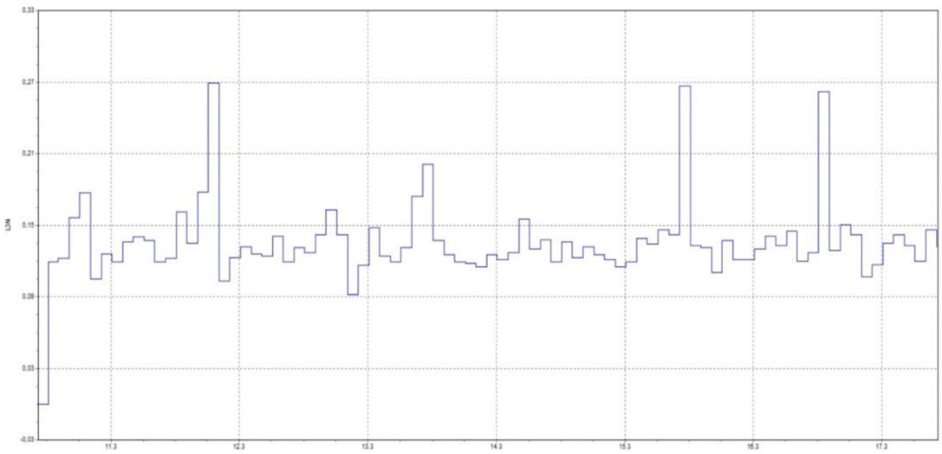

Figure 6. Long term flicker – LED

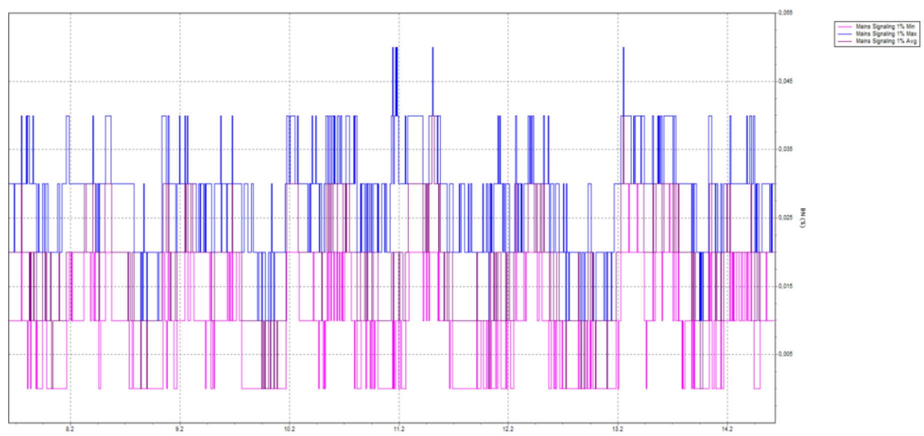

Figure 7. Mains signalling voltages – LED

The presence of mains signalling voltages are also recorded in the power quality measurements. Recorded values for both cases (HPS and LED) are far below the limits prescribed by the standard EN 50160. In comparison with HPS, mains signalling voltages are slightly higher in the case of LED. Just because of the presence of such signals, as this is not a common case, an example of an LED case is shown in this chapter, Figure 7.

Active power and reactive power have also been recorded during the measurements of power quality. Replacement of old HPS based lamps with LED technology resulted in energy savings. Except the savings in active power, positive impact on reactive power and power factor is also analysed. Thus, Figure 8 shows 7-day measurements of power and power factor for HPS. It can be noted that the power factor is really low (0.44 inductive) which results in higher reactive power (3.79 kVAr). In comparison with HPS, LED technology has an improved power factor (0.95 capacitive) and decreased reactive power (0.06 kVAr), Figure 9. Figure 9 also shows huge loads in certain moments. It can be assumed that great inrush current has been recorded because LED lamp contains power electronic device, i.e. LED driver. After stabilization, active power amounts to 0.17 kW as shown in lamp specification.

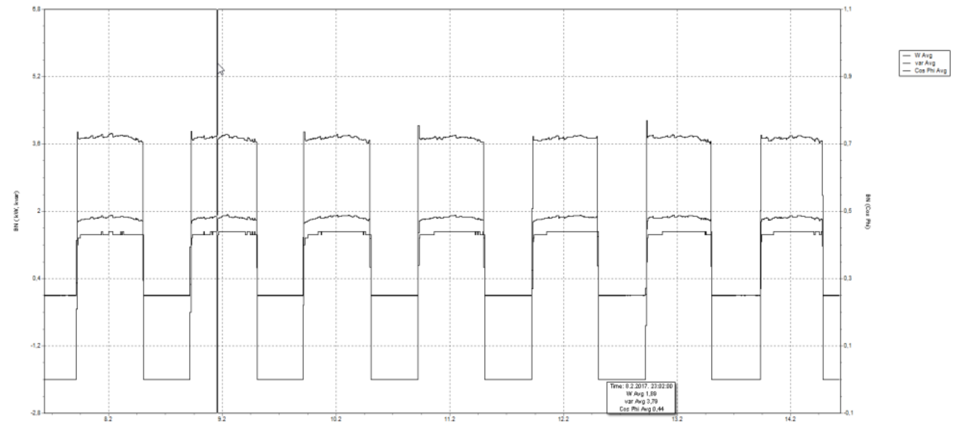

Figure 8. Active power, reactive power and power factor – HPS

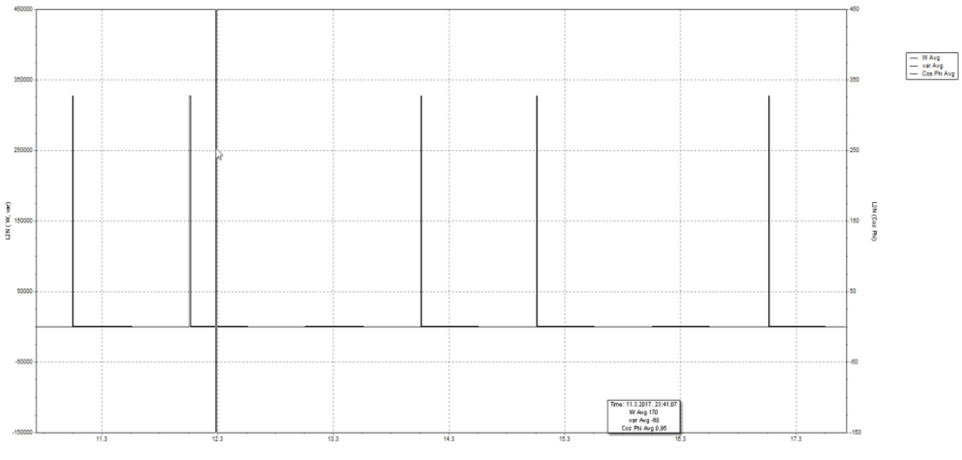

Figure 9. Active power, reactive power and power factor – LED

5. CONCLUSION

Measurement and analysis of power quality in public lighting for two cases (HPS and LED technology) show compliance of power quality parameters with the standard EN 50160. Both cases were compared and the final conclusion based on the results is presented below. All power quality parameters are within the limitations prescribed by the standard EN 50160. Measurements in accordance with the relating to voltage dips and swells did not record a single event, meaning there are no unacceptable voltage dips and swells. The comparison of HPS and LED technologies showed that in the case of LED technology THD is higher by 0.25 % in absolute value than in the case of HPS. Results of the long term flicker analysis showed that HPS technology is more stable since there are not so many peaks as in LED technology.

Although the mean values of long term flickers are approximately equal, HPS has no significant deviations from the overall weekly trend. Also, presence of mains signalling voltages in very low percentage is recorded (less than 1 %). Namely, the Croatian national energy company manages the public lighting system through the power line communication method, which uses the technology of coded signal injection of certain frequency in different voltage level distribution network. Frequency range of injected signals ranges from 200 Hz to 1,600 Hz. Recorded values in both cases (HPS and LED) are far below the limitations prescribed in the standard EN 50160. Along with the measurement of power voltage parameters, power (active and reactive) and power factor measurements were conducted. In the case of HPS, active power of 1.89 kW, reactive power of 3.79 kVAr inductive and power factor of 0.44 are recorded. Low power factor for HPS is a result of HPS based lamp as inductive load with defective condenser. Such a lamp dampens the grid with reactive power. Unlike the HPS, active power of 0.17 kW is recorded in LED case what results with savings of 89 %. Drastic change in reactive power (0.06 kVAr) is noted as well but in capacitive area due to LED lamp contains power electronic components. By implementing LED lighting, the power factor is improved (0.95). Generally, LED lighting improves voltage conditions in the distribution network because it is capacitive load while most of loads in the network are inductive. In this regard, LED lighting behaves as some type of reactive power compensator.

Analysis of power measurement results of LED lamps showed unusual curve where in 5 of 7 days power peaks appeared as a result of huge inrush current. It can be assumed that LED driver does not have an inrush current limiter (e.g. NTC)

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