ECAI 2018 - International Conference – 10th Edition
Electronics, Computers and Artificial Intelligence
28 June -30 June, 2018, Iasi, ROMÂNIA

LED performance analysis under various current waveforms

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Abstract **– The paper is addressing an important factor in LED performance, which is the behavior of these devices under various current waveforms, mainly rectangular and triangular types. More, the study is a practical recognition on how LED devices can perform at different switching periods with low frequency ripples in the range of 0 to 100%. The practical measurements are made on three types of LEDs, showing their performance under the same general test conditions.**

Keywords- Light emitting diodes; Switching frequency; Current control; Power control; Flickering light; Energy efficiency; Duty cycle.

I. Introduction

Because of its superior performances in efficacy, Light Emitting Diodes (LED) have become a usual solution for artificial lighting. Some general development rules are needed to be followed in order for technology to be used efficiently. This rules are mainly related with the energy conversion from the input source and the control method of the LED current. The paper is analyzing the performances based only on the LED current effects.

Taking into account the optical behavior, lifespan and the efficacy of LEDs, the minimization of the low frequency current ripples represents a main research topic [1-3]. Therefore, in designing a high quality LED lighting systems, a good practice is considered if low ripple on the LED current is achieved.

In relation with the optical behavior, in some cases [4-6], for frequencies higher than 100Hz, it is stated that current ripples do not represent an important problem if the percent flicker is restricted in order to minimize risks to human health. For these value of frequencies [7], for most people, the light flicker is invisible. At frequencies higher than 300 Hz the stroboscopic effect from flicker, which have a negative impact for human vision, is permanently avoided.

Taking into account all these aspects, the paper is presenting practical measurements on three types of LEDs, under different high frequency current waveforms and duty-cycles, with or without 100Hz low frequency ripples. One main objective of the paper is to highlight the performance of the LEDs under high switching frequency, which could be advantageous in practical applications by the minimization of the output filter needed.

The paper is organized with an introduction that is followed by the sections II and III where the test conditions and the practical measurements regarding the LED performances are presented. Finally, the conclusion states the main findings of the study, pointing out the best performances obtained.

II. Test Conditions

The LED test conditions are based on applying various current waveforms (DC- continuous, rectangular and triangular), different switching frequencies (10-70kHz) and duty-cycles (10, 30 and 50%). In Fig. 1, the basic converters topologies and

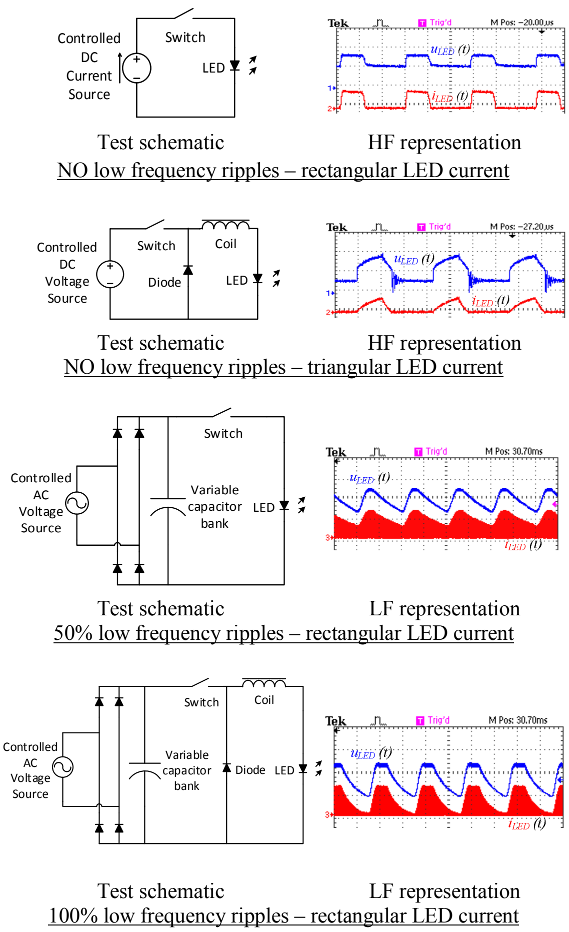


Fig. 1. LED general test conditions

switching signals used during tests at 30% duty-cycle for the rectangular and triangular LED currents are being exemplified. Also, it should be noted that the testing was done with no low frequency current ripples for the first 2 types, with 50% low frequency ripple for the 3th type and with 100% low frequency ripple for the 4th type. For obtaining the low frequency current ripples a variable capacitor bank was used. Three types of LEDs are used in the study: CREE-XLamp CXA1304, CITIZEN- CLU028-1202C4-40AL7K3 and OPTOFLASH-OF-LM002-5B380.

III. Practical Measurements

In this section, the practical measurements are being presented. It should be noted that the power on each LED type is kept at 8 W for all the tests and a maximum of 50% duty-cycle to ensure a DCM of the LED current.

For the results presented in Fig.2, the tests are made with DC, rectangular and triangular LED currents, in a 15 minutes time frame, showing both the illuminance and the temperature slopes. It should be noted that the tests are done with no low frequency current ripples. In particular, the temperature rising slope in Fig.2b is smaller in triangular current shape than in the rectangular one. For the Fig.2a and Fig.2c the slopes in rectangular and triangular current waveforms are fairly similar. In Fig.2c has an interesting behavior under rectangular current, namely the illuminance increases with temperature. In the same case, under triangular current, the illuminance is quite the same regardless of the temperature rising. Considering the triangular case, the temperature and illuminance are higher compared to the DC mode, because it has the highest peak current.

Considering the illuminance, all the results show that all LED types perform best under triangular, followed by the rectangular and lastly the DC current waveforms. The temperature rising undergoes the smallest slope for the continuous DC mode. Also, under continuous current waveform, one can notice that in the beginning of the functioning cycle, all the LEDs exhibit a sharp decrease in illuminance.

Referring to Fig. 3, Fig. 4 and Table 1, it is necessary to specify that during these tests a constant LED temperature of 40°C was maintained in all the tests. In Fig.3 and Fig. 4 is shown the illuminance dependence on the four variables mentioned (current waveforms, duty-cycles, different switching frequencies and with / without low frequency ripples). Referring to the switching frequency (10…70kHz) and duty-cycles (10, 30 and 50%), for all three types of LEDs, the overall tendency is that the illuminance increases with increasing frequency and duty-cycles. By looking at the dependence on the current shape, the best results were obtained with the triangular waveforms. Finally, there is an inverse dependence of the illuminance relative to the increase of the low frequency current ripple.

As general rules, the tests show that all LED types perform best under triangular current waveform, at high switching frequency and duty cycles with no low frequency ripples. Table 1 shows the obtained illuminance records for the case of CREE LEDs in all the cases studied.

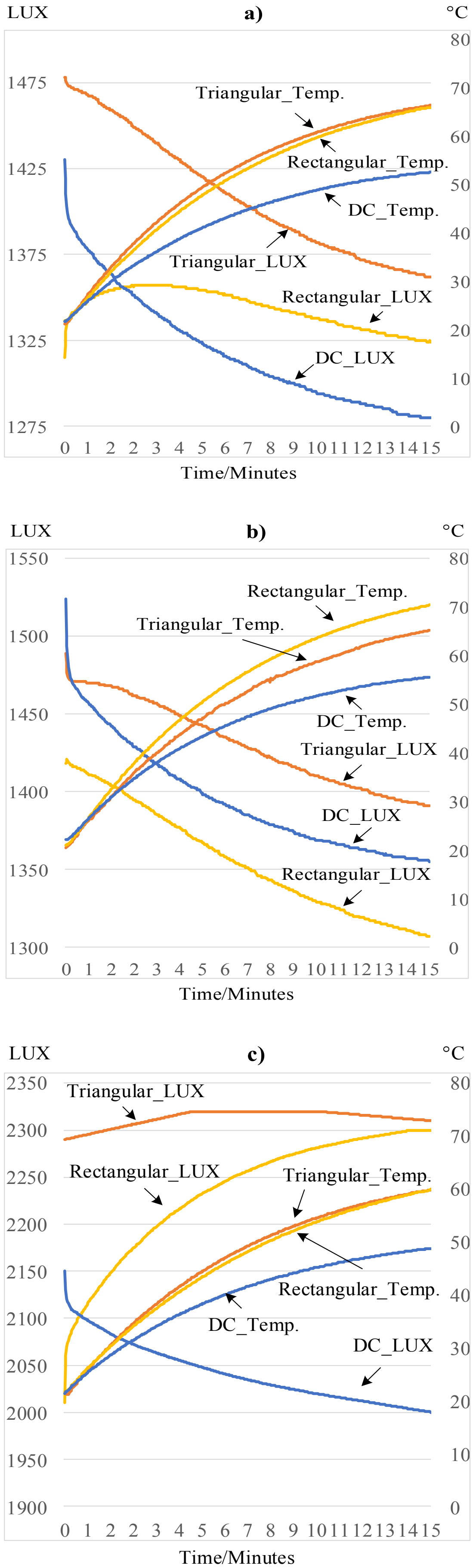
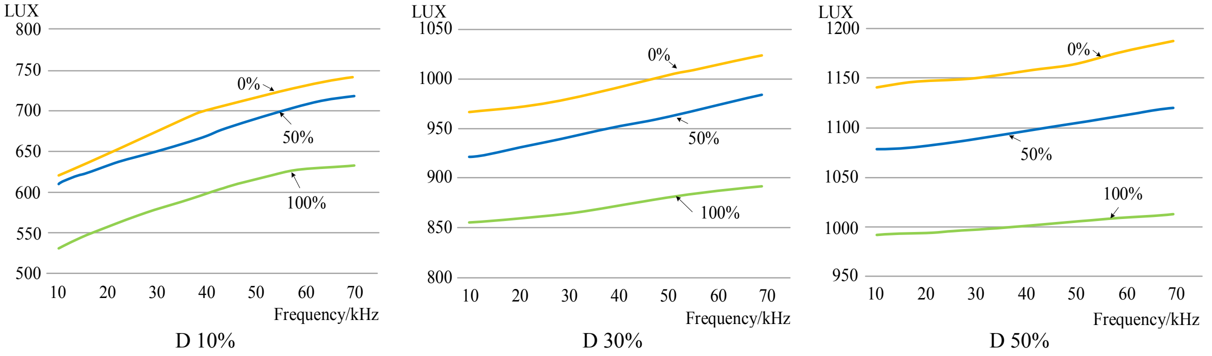
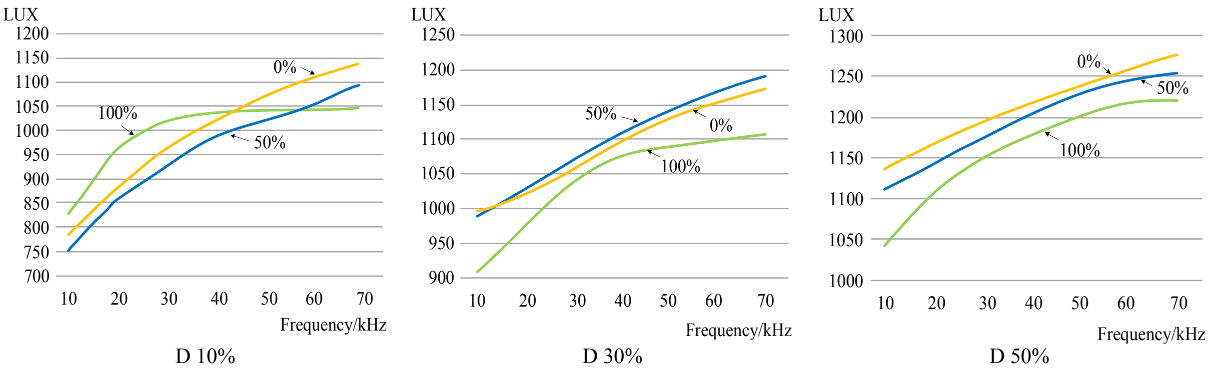


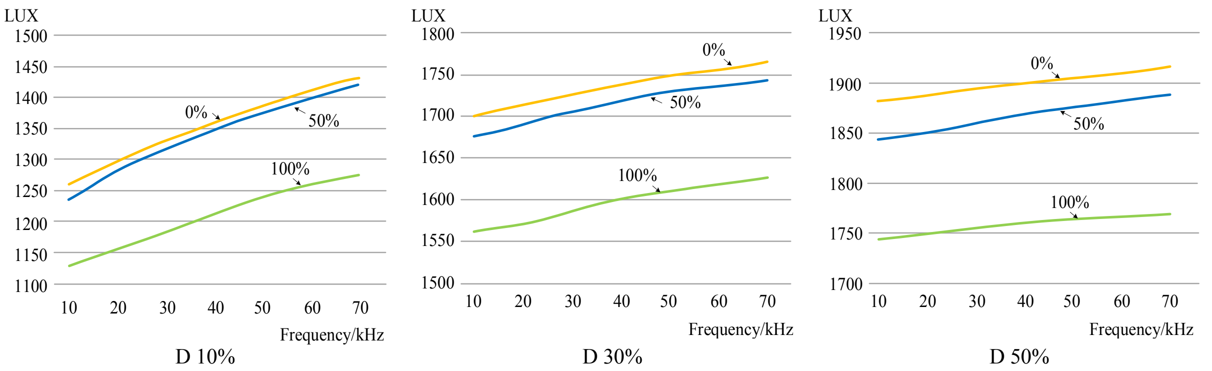
Fig. 2. Tests results for different LED types under various current waveforms, frequencies and duty-cycles (a – CREE; b – CITIZEN; c– OPTOFLASH)



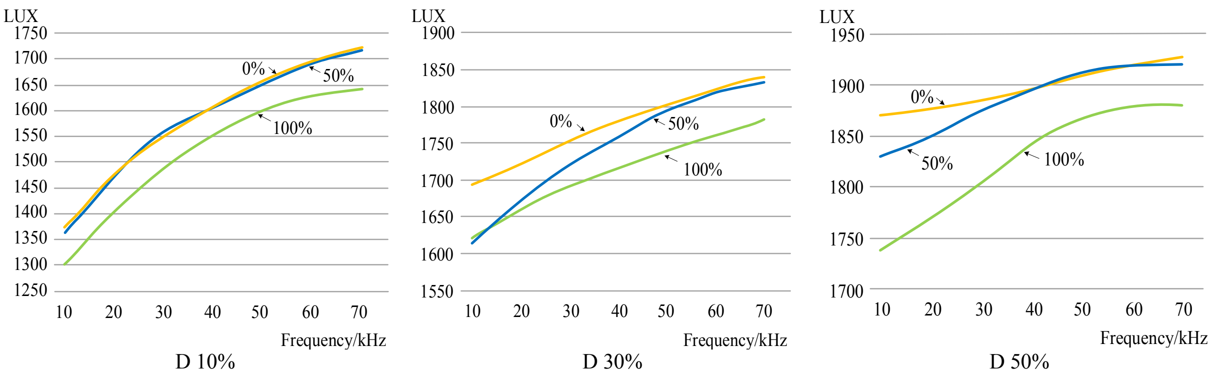
CREE LED with rectangular waveform current



CREE LED with triangular waveform current



CITIZEN LED with rectangular waveform current



CITIZEN LED with triangular waveform current

Fig. 3. Tests results for different LED types under various current waveforms, frequencies and duty-cycles (Cree, Citizen LED)

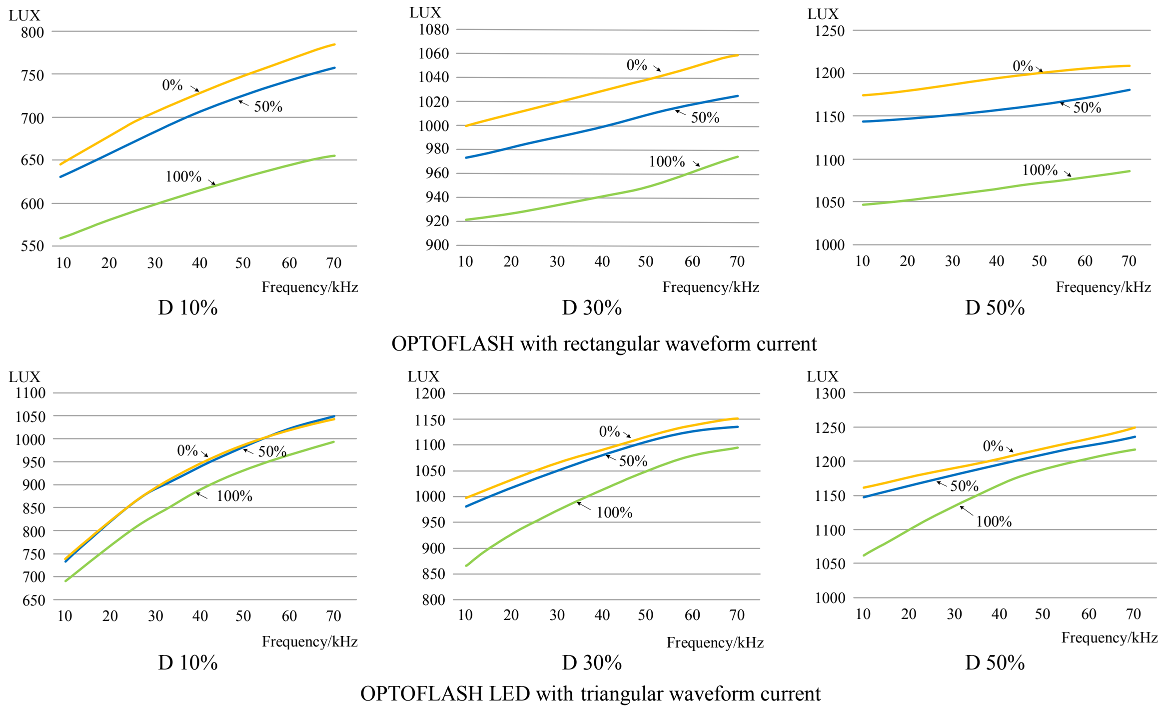


Fig. 4. Tests results for different LED types under various current waveforms, frequencies and duty-cycles (OPTOFLASH LED)

Current waveform	Triangular							Rectangular						
Frequency / kHz	10	20	30	40	50	60	70	10	20	30	40	50	60	70
LUX; D-10%; 0% LF Ripple.	785	880	960	1016	1070	1107	1140	620	644	668	698	716	728	740
LUX; D-10%; 50% LF Ripple.	753	858	923	984	1020	1048	1090	609	632	650	668	688	705	716
LUX; D-10%; 100% LF Ripple.	827	961	1029	1032	1034	1030	1020	530	555	580	595	609	627	632
LUX; D-30%; 0% LF Ripple.	996	1023	1062	1096	1133	1154	1174	966	970	978	989	1001	1012	1022
LUX; D-30%; 50% LF Ripple.	990	1030	1070	1105	1142	1168	1192	920	930	939	950	960	972	983
LUX; D-30%; 100% LF Ripple.	911	975	1042	1075	1089	1100	1108	854	858	863	870	879	885	890
LUX; D-50%; 0% LF Ripple.	1139	1170	1195	1217	1240	1280	1278	1140	1146	1149	1156	1163	1176	1186
LUX; D-50%; 50% LF Ripple.	1112	1145	1175	1205	1229	1245	1255	1077	1080	1088	1095	1104	1112	1118
LUX; D-50%; 100% LF Ripple.	1043	1109	1152	1180	1200	1220	1222	990	993	995	1000	1004	1007	1011

Table. 1. Tests results for the CREE LED under various current waveforms, frequencies, duty-cycles and with / without low frequency ripples.

IV. Conclusion

As a result of the analyzes carried out on the three types of LED, it is found that the best results were obtained with the triangular current waveform at high switching frequency, 50% duty-cycle and without low frequency ripples. Another important conclusion is that at 50% (low frequency ripples) the results are very close to those in which this was 0%. This automatically translates into a reduction in filtering required at the input of the converter, with direct implications for the cost price and the possibility of using capacitors with a longer lifetime (e.g. ceramic or film type).

Acknowledgment

This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI – UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0391 / CIA_CLIM - Smart buildings adaptable to the climate change effects, within PNCDI III

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