Impact factors in LED lamp measurement reproducibility

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The aim of this paper is to study the reproducibility of measurements in LED lamps. For research purposes as well as for standardized tests, there is a need for measurements to be reproducible so that results can be accurately compared. The knowledge regarding which parameters and test conditions will influence the results is therefore crucial. This paper aims at identifying how changes in supply voltage and ambient conditions impact the results and defining a methodology to determine when an LED lamp is considered stable. The paper describes the differences in illuminance and active power under different ambient conditions and supply voltages for several LED lamps for indoor use. Variations in illuminance and active power are also studied within the stabilisation time. A consistent methodology for temperature measurement is explained and used in this paper.

1. Introduction

Due to their low consumption, good efficiency and high durability, LED lamps are currently used for many applications in domestic use as well as in street lighting. However, the optical characteristics, reliability and lifetime of LED lamps strongly depend on their temperature.1,2 There have been many reports about early failures of lamps that have been seen as a barrier in the public acceptance of LED lamps.3-5 The temperature, ambient as well as internal, is always a crucial issue for LED product development. Manufacures indicate in datasheets6,7 the temperature dependency of certain parameters, e.g. the temperature coefficient of voltage and light output.

When testing a device, regardless of the aim being time of failure, light output quality or some power quality index, it is important to eliminate uncertainties affecting the reproducibility of the aforementioned tests. These uncertainties can be e.g. variations in the voltage feeding the lamp or variations in the ambient temperature during the measurement. To achieve better reproducibility when measuring LED lamps, it is recommended to allow the lamp burning for a certain amount of time, i.e. enough time to reach a stable operating temperature. IEC standard 61000-3-28 states an operation time of at least 15 min before testing discharge lamps. It also states that some types of lamps require more time and that the corresponding standard should be applied, EN 62612:20139 for LED lamps. EN 62612:20139 defines the stabilisation time as the time needed to reach
stable photometric conditions and links thermal stabilisation with light output stabilisation as EN 13032-4:2015\textsuperscript{10} also does.

Stating a correct thermal stabilisation time is imperative to make tests and benchmarking reproducible, since different temperatures can lead to different measurement results. EN 13032-4:2015\textsuperscript{10} states the strongly relationship between the stabilisation of LED lamps and the thermal equilibrium of the components, but does not state how to define the thermal stabilisation. The LED lamp capacitor is a key component in supraharmonic immunity tests that is sensitive to thermal stabilisation. When testing flicker, it must be ensured that changes in illuminance are due to external voltage variations, not due to stabilisation issues. However, in contrast to what is stated in the standard, Luo et al.\textsuperscript{11} showed that the temperature of an 80 W LED streetlamp is stabilised only after an operation time of several hours. Similar results were found by Luo et al.\textsuperscript{3} with a 114 W LED streetlamp. The aforementioned studies only considered the thermal characteristic of the LED lamps without considering the light output or electrical parameters.

The purpose of the study by Sakar et al.\textsuperscript{12} was to analyse the impact from voltage fluctuations on the light intensity (flicker) during thermal stabilisation of LED lamps, showing that the impact decreases with time. Sakar et al.\textsuperscript{12} recommended a measurement period of at least 60 min for residential LED lamps in order to ensure reproducibility. Only the illuminance was used as a parameter to determine the thermal stabilisation of the lamps. In another study,\textsuperscript{13} compact florescent lamps as well as one LED lamp were subjected to rectangular modulated voltage variations for immunity testing. Although the focus of this study was immunity testing, the sufficient stabilisation time was indicated between 10 min and 15 min depending on the lamp.

This paper presents a novel methodology for determining when LED lamps are stable enough for reproducible tests. Aside from illuminance and active power as is proposed in EN 62612:2013 and EN 13032-4:2015, the methodology also utilizes the temperature of the lamp. The focus goes further than measurements done in a standard ambient condition or to test the device quality. The effect of cooling continuously the LED lamps with a fan during a test is analysed from a stabilisation point of view. Although the standard EN 13032-4:2015 recommends measuring with still air, LED lamps can be used close to an air conditioning or a fan in household, offices or shopping centres, as examples. The results cooling with a fan are also compared with the results without the fan cooling for each parameter studied feeding with different voltage magnitudes. The results presented in this paper show that the stabilisation time varies for each parameter; which one to consider depends on the accuracy or level of reproducibility needed. It has also been observed that the stabilisation of the LED lamp influences the measurement of electrical parameters such as total harmonic distortion (THD) and current rms, but this is not shown here since it is not relevant for the aim of this paper.

2. Measurement setup

2.1 Test platform

The platform is composed of a wooden base where a cap has been set to keep constant distance between the studied lamp and the measurement devices, and a paperboard box that encloses the LED lamp to avoid light disturbances during the measurements. The platform contains the sensor of the illuminance meter E4-X from Hagner (Resolution: 1 lx/mV, with internal temperature compensation), the thermal camera Ti45FT from Fluke (emissivity: 0.95, lens: 20 mm, focal relation (F): 0.8) and the fan 3610KL-05W-B50 from Minebea Mitsumi (20 V dc). The components are kept in the
position shown in Figure 1 for all the tests of each LED lamp.

A Yokogawa DL850E oscilloscope is used for the measurements. Three channels are used: voltage (analogue module, 100 kS/s and 16-Bit), current (Pearson current probe 411 acquired with the voltage analogue input module, 1 MS/s and 16-Bit) and light output (same module as for the current). All measurements are synchronised. The thermal camera records the temperature of the LED lamp. The measurement setup is shown in Figure 1.\textsuperscript{14}

2.2 LED lamps tested

The list of LED lamps tested is given in Table 1. LED lamps currently available in the European market have been tested during periods of up to 90 min. Four different brands have been chosen, with powers from 5 to 12 W. The luminance of the lamps provided by the manufacturers varies from 350 to 1055 lm. Most of the lamps are standard E27 LED bulbs, only LED 9 has GU10 base.

3. Method

3.1 Test conditions

The supply voltage frequency was 50 Hz. The temperature in the laboratory was 24°C ± 0.5°C. The acquisition frequency of the oscilloscope was set to 1 MS/s with a 0.2 s window as recommended by the IEC standard for power quality measurements, 61000-4-30.\textsuperscript{15}

The following measurements have been made to check measurement reproducibility:

– To observe the impact of the supply voltage on the stabilisation of the lamps:

  o Sinusoidal voltage waveform, 230 V rms.
  o Sinusoidal voltage with a modulation frequency of 5 Hz with an amplitude of 3% of the fundamental voltage (230 V rms) as indicated in Figure 2.

– To observe the voltage magnitude dependency of LED lamps:

  o Sinusoidal voltage waveform, 207 V rms (lower supply voltage limit given in EN 50160\textsuperscript{16} for low voltage networks).
Sinusoidal voltage waveform, 253 V rms (upper supply voltage limit given in EN 50160\textsuperscript{16} for low voltage networks).

- To observe the ambient condition dependency, all measurements were performed with and without a fan cooling the lamp.

Voltage, current, temperature and light output have been measured from \( t = 0 \) to \( t = 60 \text{ min} \) (some LED lamps have been measured until \( t = 90 \text{ min} \)), taking one sample every 10 min. The measurements were repeated after few days and compared, resulting in differences below 0.25\% in the illuminance and active power at \( t = 60 \text{ min} \).

### 3.2 Illuminance

As the illuminance varies with twice the power system frequency, the average value has been computed over the 200 ms window to obtain a single value every 10 min (7 and 10 values for the 60 and 90 min test) and get the illuminance evolution with time.

### 3.3 Temperature evolution

The temperature evolution in the LED lamps has been obtained through thermal pictures taken over time, using the hottest temperature point recorded at the last measurement (\( t = 60 \text{ or } t = 90 \text{ min} \)) as reference. Except for the first instant (\( t = 0 \text{ min} \)), when the temperature is not relevant for the thermal stabilisation study (as will be shown later), the coordinates of the hottest point remain at the same position and can be considered constant over time.

It has been studied how the initial temperature (at \( t = 0 \)) of the lamp impacts the stabilisation of the LED lamp. The initial temperature has been reduced by 33.15\°C (from 27.9\°C to \(-5.25\°C\)) for LED 5 by cooling it down in a freezer. With these new initial conditions, the illuminance, the active power and the LED lamp temperature have been measured without fan cooling and then

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**Table 1** Data of tested lamps, provided by the manufacturer

| LED number | Power (W) | Luminous flux (lm) | Correlated colour temperature (K) |
|------------|-----------|--------------------|----------------------------------|
| LED 1      | 6         | 470                | 2700                             |
| LED 2      | 9         | 806                | 2700                             |
| LED 3      | 7         | 470                | 2700                             |
| LED 4      | 8         | 806                | 3000                             |
| LED 5      | 8         | 470                | 2700                             |
| LED 6      | 12        | 806                | 2700                             |
| LED 7      | 10        | 1055               | 4000                             |
| LED 8      | 9         |                    | 6000                             |
| LED 9      | 5         | 350                | 4000                             |
| LED 10     | 6         | 400                | 3000                             |

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**Figure 2** 5 Hz modulated sinusoidal supply voltage\textsuperscript{14}
compared with the measurement starting from a warmer LED lamp temperature. As Figure 3 shows, comparing both graphs at t = 90 min for LED 5, the illuminance variation (upper Figure 3) is 1.44% (11.9 lx), the active power variation (middle Figure 3) 0.0358% (0.003 W) and the temperature variation (bottom Figure 3) −2.45 % (1.85°C). The initial condition impact measured leads to low percentages of variation in the parameters, although this percentage is significant for illuminance in LED 5.

The influence of the position of the fan within the chamber has also been considered. The area around the lamp in the thermal picture given by the thermal camera (i.e. the area excluding the lamp itself) has been considered as ambient temperature, referred to as the right and left areas in Figure 4 (around 28°C). Within each area, the average temperature has been calculated obtaining evenly changes in the ambient temperature around the LED lamp independently of the position of the fan. For both areas similar changes take place, reaching maximum 0.1°C difference between them at t = 60 min.

4. Results

4.1 Stabilisation time

The evolution of temperature, active power and illuminance over time is considered in this section, with the aim of studying the stabilisation of LED lamps. The evolution over time has been analysed as a percentage of the variation between two consecutive instances according to equations (1), (2) and (3) for temperature (°C), active power (W) and illuminance (lx). Samples have been taken each 10 min interval for a period of time up to 90 min. Positive values indicate that the value of the variable has increased from one instant.

Figure 3 LED 5 measured for two different initial temperatures without fan cooling connected to a 230 V sinusoidal supply voltage.
to another, and its absolute value indicates the percentage of variation.

\[
\Delta T(t_n) = \frac{T(t_n) - T(t_{n-1})}{T(t_{n-1})} \times 100 \quad (1)
\]

\[
\Delta P(t_n) = \frac{P(t_n) - P(t_{n-1})}{P(t_{n-1})} \times 100 \quad (2)
\]

\[
\Delta E(t_n) = \frac{E(t_n) - E(t_{n-1})}{E(t_{n-1})} \times 100 \quad (3)
\]

The stabilisation time for each parameter is defined as the lowest value of \( t_n \) applied in equations (1), (2) and (3) when the following inequalities (equations (4)–(6)) hold for each parameter (a similar definition was given by Sakar et al.\textsuperscript{12})

\[
\Delta T(t_n) \leq |1| \% \quad (4)
\]

\[
\Delta P(t_n) \leq |1| \% \quad (5)
\]

\[
\Delta E(t_n) \leq |0.5| \% \quad (6)
\]

Apart from these parameters, different supply voltage magnitudes, such as 207 V rms and 253 V rms (undervoltage and overvoltage, respectively), have also been considered in terms of stabilisation time, but they were found to not influence it.

4.1.1 Temperature evolution

EN 62612:2013 only considers a threshold of variation for power (1%) and light output (0.5%) regarding LED lamp stabilisation. In this paper, the threshold for the temperature variation has been similarly set to ±1\% (red dotted lines in Figures 5 and 6).

The LED lamp samples were connected to different voltage waveforms (sinusoidal and 5 Hz modulation) with and without a fan. The resulting temperature variations are shown in Figure 5.

Starting with a sinusoidal voltage waveform without the fan connected (left side of Figure 5), the variation between minute 50 and 60 is 1\% or below for 70\% of the lamps.
Figure 5  Temperature variation (%) of different LED lamps connected to a pure sinusoidal 230 V rms source without a fan cooling the lamps (left), and with a fan cooling the lamps (right). Time axes represent ($t_n$).

Figure 6  Active power variation (%) of different LED lamps for all the cases studied. Without a fan cooling the lamps (left), and with a fan cooling the lamps (right). Lamps fed with sinusoidal voltage (upper row) and with a modulated voltage (lower row). Time axes represent ($t_n$).
Two of the lamps that did not reach 1% at minute 60 were measured for a longer time. In their case, the difference between temperatures at minute 70 compared to minute 60 was 0.98% and 0.66% respectively.

The thermal stabilisation time from this temperature study is 60 min for 70% of LED lamps tested and 70 min for 30% of them, similar to the results from Sakar et al.,

In order to know how external ambient conditions influence the thermal evolution in LED lamps (e.g. when LED lamps are subjected to cooler ambient conditions), the same test was repeated with a pure sinusoidal voltage waveform but with a fan cooling the lamps. The results are shown in Figure 5 (right side). The addition of the fan reduced the temperature of the LED lamps with approximately 25–40% when they are stable and it can be seen that a cooler LED lamp temperature leads to a shorter thermal stabilisation time (40 min, except for LED 1 for which it took 50 min) compared to the previous case without a fan.

The other effect considered in the temperature stabilisation study is when lamps are connected to a voltage waveform with a 5 Hz

Figure 7  Illuminance variation (%) of different LED lamps for all the cases studied. Without a fan cooling the lamps (left), and with a fan cooling the lamps (right). Lamps fed with a sinusoidal voltage (upper row) and with a modulated voltage (lower row). Time axes represent $t_n$. 

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modulation frequency. With this test, the stabilisation time dependency with the supply voltage is studied without and with a fan cooling the lamps. The temperature evolution with a 5 Hz modulation frequency in the supply voltage is similar to the results obtained when lamps were connected to a pure sinusoidal voltage waveform (Figure 5), without and with a fan cooling the lamps. The stabilisation time can also in this case be considered 70 min and 50 min respectively, considering the maximum stabilisation time obtained from the set of LED lamps tested in this study.

4.1.2 Active power evolution

As it can be seen from Figure 6, the active power of all the lamps (except LED 2) decreases with time (negative percentage of variation) as was already shown by Sakar et al. and Gil-de-Castro et al. After minute 30 (minute 20 for LED 8 when connected to a 5 Hz modulation voltage), there are slight variations in the active power (it either increases or decreases). To know the stabilisation time according to the active power, the variation in active power should satisfy inequality (5) where standard EN 62612 suggests a variation of 1% as the threshold. According to that, the stabilisation time is 30 min for this set of lamps either with or without a 5 Hz modulation frequency in the supply voltage, and without cooling. When cooling with a fan, the stabilisation time becomes shorter (20 min) which was also seen for the temperature stabilisation time.

4.1.3 Illuminance evolution

As with active power, all the LED lamps decrease in illuminance with time (Figure 7), as also shown by Sakar et al. For the cases where the lamps are cooled with a fan there are some slight increases after the stabilisation is reached. To know the stabilisation time according to illuminance, the variation in illuminance should satisfy inequality (6) where EN 62612 suggests a variation of 0.5% as the threshold. According to that, the stabilisation time for these lamps is 50 min without a fan and 30 min with a fan.

4.2 Voltage magnitude dependency of LED lamps

To observe the voltage magnitude dependency of LED lamps, a sinusoidal voltage with 5 Hz frequency modulation, as well as undervoltage and overvoltage with the amplitudes described in the methodology section have been applied. The test for each voltage supply has been done both with and without a fan to consider the impact of the ambient conditions.

4.2.1 Active Power

Figure 8 shows a plot of the active power against temperature for LED 4 (left) and LED 5 (right) under different supply voltages (shown as different colours/markers), with and without a fan (shown as filled and unfilled polygons).

Evaluating the voltage magnitude dependency with the measurements where a fan is cooling (comparison between filled polygons of different colour/marker) and following equation (7) where the measurement of 230 V rms is the reference.

\[
\Delta P = \frac{P - P_{ref}}{P_{ref}} \times 100
\]  

- For LED 4, the maximum variation in active power under different supply voltages is 0.03 W/0.4%. For this LED lamp, voltage variations do not affect the power in a significant way.
- For LED 5, a decrease in active power of 10% can be seen when the undervoltage is applied. A similar behaviour can be seen when the overvoltage is applied, with an increase in active power of 8%. With a voltage modulation of 5 Hz, the active power is 0.4 W (5%) higher than...
for a pure sinusoidal waveform (denoted 230 V in Figure 8).

To study the impact from the ambient condition on the effect of different supply voltage magnitudes, measurements with (filled polygons) and without (unfilled polygons) a fan cooling the lamp with the same supply voltage (shown as same colour/marker) were compared using equation (8).

\[
\Delta P = \frac{P_{\text{fan}} - P}{P} \times 100 \tag{8}
\]

- For LED 4 this difference is between 0.19 W (2.4%) (difference between blue filled and unfilled circles) and 0.23 W (2.9%) (difference between orange filled and unfilled squares).
- For LED 5, the largest difference in active power can be seen when the lamp is fed with the overvoltage (0.12 W (1.3%), difference between pink filled and unfilled diamonds in the right-hand side of Figure 8).

These two LED lamps behave differently regarding the active power when fed by different supply voltage magnitudes, both with and without a fan. However, the active power variation in absolute values is small in both cases due to the low consumption of LED lamps.

### 4.2.2 Illuminance

Figure 9 shows a plot of the illuminance against temperature for LED 4 (left) and LED 5 (right) under different supply voltages (shown as different colours/markers), with and without a fan (shown as filled and unfilled polygons).

Evaluating the voltage magnitude dependency with the measurements where a fan is cooling (comparison between filled polygons of different colour/marker) and following equation (9) where the measurement of 230 V rms is the reference.

\[
\Delta E = \frac{E - E_{\text{ref}}}{E_{\text{ref}}} \times 100 \tag{9}
\]

- For LED 4, the maximum illuminance variation is 31 lx (2.25%) (blue-filled circles).
- For LED 5, the variations in illuminance when applying the undervoltage and overvoltage are
6.8% and 7.7%, respectively. As with the active power, the illuminance variation for a supply voltage with a modulation frequency of 5 Hz is not as large as for the undervoltage or overvoltage, with a variation of just 1.12%.

To study the impact from the ambient condition on the effect of different supply voltage magnitudes, measurements with (filled polygons) and without (unfilled polygons) a fan cooling the lamp with the same supply voltage (shown as same colour/marker) were compared following equation (10).

$$\Delta E = \frac{E_{fan} - E}{E} \cdot 100$$ (10)

– For LED 4, the results without a fan (unfilled polygons) do not follow the same behaviour as the measurements with a fan (filled polygons). The range of variation is between 3.98% (difference between pink filled and unfilled diamonds) and 6.69% (differences between green filled and unfilled triangles). Despite of this, if the results without a fan (unfilled polygons) are used for studying the dependency between illuminance and voltage, the maximum variation in illuminance between different voltage supplies (unfilled polygons of different colours/markers) is 35 lx (2.7%), close to the result obtained with a fan 31 lx (2.25%), taking again the sinusoidal 230 V supply voltage as the reference.

– For LED 5, the illuminance variation is within 2.75% (difference between orange filled and unfilled squares) and 3.13% (difference between green filled and unfilled triangles), except when the LED lamp is fed with 253 V (differences between pink filled and unfilled diamonds). In this case, the variation is 4.87%. For this lamp, the impact of an overvoltage on the illuminance is bigger than the impact of an undervoltage when cooling with fan, and the opposite when not cooling with fan. No general conclusion can therefore be drawn on which condition has the stronger impact.

It has been shown that undervoltages and overvoltages have a bigger impact on the active power than on the illuminance for LED 5, and the opposite for LED 4. Comparing both LED lamps, LED 5 has more dependency on the voltage magnitude. This implies that for certain lamps, the efficiency changes

*Figure 9* Illuminance against temperature from t = 40 min for different supply voltages (different colours/markers) with (filled polygons) and without (unfilled polygons) a fan cooling the lamp. LED 4 is shown on the left and LED 5 on the right.
with the voltage magnitude of the supply voltage. In this paper, two different behaviours have been shown for LED lamps when supplied by undervoltages and overvoltages.

5. Discussion

A consistent reference to observe the temperature evolution has been found in the hottest point taken at the last instant measured. The coordinates for the hottest point remain constant over time, except for the initial instant when the LED lamp is just turned on (from minute 10 or less the hottest point remains its position), being the initial conditions non-influential for the reached stabilisation values.

Table 2 shows the qualitative assessment of when all LED lamps tested are stable for each test. Results are the same for the tests with a 5 Hz frequency modulation in the supply voltage, with the conclusion that rms variations in the supply voltage have no impact on the stabilisation time. The temperature shows the longest stabilisation time, both for measurements with and without a fan. Hence, the temperature stabilisation time determines the LED lamp stabilisation time. The lamps can be considered stable after 70 min when the ambient temperature is 28°C but the time changes depending on the ambient conditions as shown when the fan is cooling the LED lamp.

Table 2 Qualitative assessment of the maximum stabilisation time for each parameter with and without fan and for sinusoidal and modulated supply voltages observed in LED lamps from this study

| Parameter          | Sinusoidal/ modulated without fan | Sinusoidal/ modulated with fan |
|--------------------|-----------------------------------|--------------------------------|
| Temperature        | 70 min                            | 50 min                         |
| Active power       | 30 min                            | 20 min                         |
| Illuminance        | 50 min                            | 30 min                         |

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Two different cases are observed regarding the impact of overvoltages and undervoltages on the illuminance and active power. In LED 4, the impact is small, while in LED 5, the impact is significant. In addition, for LED 4 the difference between measurements due to variations in temperature is bigger than due to undervoltages and overvoltages, with the opposite for the other LED lamp. It has been shown that undervoltages and overvoltages have a bigger impact on the illuminance than on the active power for LED 4, and the opposite for LED 5. This means that variations in the voltage magnitude or temperature can affect the reproducibility of measurements, although some LED lamps are more sensitive than others.

The stabilisation time tests show that the time before an LED lamp can be considered stable depends on the individual lamp type as well as on ambient conditions. The results also show a dependency on the voltage magnitude on both illuminance and active power for certain LED lamps, the stabilisation time is unaffected. For this reason, it is necessary to follow the recommendations in Table 3 for a good reproducibility and therefore consistent measurements.

In Table 3, ambient conditions refer to temperature and circulated air for indoor tests but other atmospheric phenomena may be added for outdoor tests. An example of a possible change is the change of the circulated air when opening and closing a door or a window, or when a heater is turned on.

It should be noted that the initial LED lamp condition may affect the reproducibility when the LED lamp reaches the stabilisation mainly in terms of illuminance.

As stabilisation is evaluated based on the difference between two instants (10 min interval between instants) as indicated in equations (1), (2) and (3), a different time interval may change the evaluation of the stabilisation time since, in practice, the LED lamp reaches stabilisation in an unknown instant between $t_n$ and $t_{n-1}$.
Table 3  Generalized recommendations for reproducibility under any ambient condition

| Recommendation                                                                 |
|--------------------------------------------------------------------------------|
| Keep ambient conditions constant throughout the tests.                         |
| Be aware about any possible change of the ambient conditions.                  |
| Ensure that the supply voltage has the expected amplitude.                     |
| Measure the temperature evolution of the LED lamp to check its stabilisation time regarding ambient conditions. |
| Be aware that the stabilisation time could change for different models of LED lamps. |

Table 3 shows the qualitative assessment of impact factors in LED measurement reproducibility. The authors have shown for LED lamps when undervoltages and overvoltages have a bigger impact on the illuminance than on the active power. For this reason, thermal stabilisation time differs for different LED lamps and different ambient conditions. As the LED lamps were sensitive to changes in ambient conditions, the ambient conditions should be kept constant during comparative tests. The stabilisation time is not affected by changes in supply voltage magnitude.

Based on the performed tests, it was found that the temperature takes the longest to stabilise, compared to the illuminance and active power. For this reason, thermal stabilisation is considered the reference to know when the LED lamp is stable before doing more measurements. It is also shown that the stabilisation time differs for different LED lamps and different ambient conditions. As the LED lamps were sensitive to changes in ambient conditions, the ambient conditions should be kept constant during comparative tests. The stabilisation time is not affected by changes in supply voltage magnitude.

The dependency of LED lamps on changes in the voltage magnitude differs, as shown for LED 4 and LED 5 in Section 4.2.

Recommendations for reproducibility that are proposed in this paper should be followed to perform consistent tests. The recommendations should be applied for every different model of LED lamp and every time that there are different ambient conditions even if it is the same LED lamp model being tested.

The initial temperature does not define the stabilisation temperature, it is defined by the ambient conditions and electrical features of LED lamps.

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