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Edition 3.0 2020-07

TECHNICAL REPORT

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Equipment for general lighting purposes – EMC immunity requirements – Part 1: Objective light flickermeter and voltage fluctuation immunity test method

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

EQUIPMENT FOR GENERAL LIGHTING PURPOSES – EMC IMMUNITY REQUIREMENTS –

Part 1: Objective light flickermeter and voltage fluctuation immunity test method

FOREWORD

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IEC TR 61547-1, which is a Technical Report, has been prepared by IEC technical committee 34: Lighting.

This third edition cancels and replaces the second edition published in 2017. This edition constitutes a technical revision.

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This edition includes the following significant technical changes with respect to the previous edition:

a) the scope of this document has been clarified to make a distinction between flicker testing without voltage fluctuations to measure the intrinsic performance of lighting equipment and flicker testing in which a specific set of voltage fluctuations are applied in order to measure the immunity of the lighting equipment to voltage fluctuations present on the mains;

b) the test procedure for flicker testing has been clarified.

The text of this Technical Report is based on the following documents:

Draft TR	Report on voting
34/668/DTR	34/701/RVDTR

Full information on the voting for the approval of this Technical Report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61547 series, published under the general title *Equipment for general lighting purposes – EMC immunity requirements*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

The fast rate at which solid state light (SSL) sources can change their intensity is one of the main drivers behind the revolution in the lighting world and applications of lighting. Linked to the fast rate of the intensity change is a direct transfer of the modulation of the driving current, both intended and unintended, to a modulation of the luminous output. This light modulation can give rise to changes in the perception of the environment. While in some very specific entertainment, scientific or industrial applications a change of perception due to light modulation is desired, for most everyday applications and activities the change is detrimental and undesired. These changes in the perception of the environment are called "temporal light artefacts" (TLAs) and can have a large influence on the judgment of the light quality. Moreover, the visible modulation of light can lead to a decrease in performance, increased fatigue as well as health problems like epileptic seizures and migraine episodes [17][18][1].

Different terms exist to describe the different types of TLAs that may be perceived by humans. The term "flicker" refers to light variation that may be directly perceived by an observer. "Stroboscopic effect" is an effect which may become visible for an observer when a moving or rotating object is illuminated (CIE TN 006:2016 [26]).

Possible causes for light modulation of lighting equipment that may give rise to flicker or stroboscopic effect are:

– AC supply combined with light source technology and its driver topology;
– light regulation technology of externally applied light level regulators or internal light level regulators;
– mains voltage fluctuations caused by electrical apparatus connected to the mains (conducted electromagnetic disturbances) or intentionally applied for mains-signalling purposes.

Lighting products that show unacceptable flicker are considered as poor-quality lighting.

This document provides a description of an objective light flickermeter and a method for measuring the intrinsic flicker of lighting equipment as well as testing the immunity of lighting equipment against mains voltage fluctuations caused by electrical apparatus connected to the mains at levels that are allowed through IEC 61000-3-3.

Flicker perception, as well as IEC 61000-3-3 and IEC 61000-4-15, the associated standards for voltage fluctuations and the flickermeter, are based on the 60 W incandescent lamp. As a result of the phasing out of incandescent lamps and the widespread introduction of alternative lighting equipment technologies, a new reference lamp was considered. It has been demonstrated that new lighting technologies are in general less but sometimes also more sensitive to supply voltage fluctuations than the current 60 W incandescent lamp. A CIGRE working group has assessed the impact of new lighting technologies on the existing flicker standards [16]. For the moment, the present flicker sensitivity curve of IEC 61000-3-3 remains as the reference. However, because of the increased diversity of sensitivity of lighting equipment to voltage fluctuations, there is a future need for a voltage-fluctuation immunity test specifically for lighting equipment. In this way, the full EMC approach (Figure 1) is introduced for flicker, i.e. with a view to limiting voltage fluctuations caused by equipment connected to the grid, and in addition to establishing a minimum level of flicker immunity of lighting equipment against these voltage fluctuations.

This document will allow the lighting industry to gain experience in flicker immunity test methods. Results of actual tests will be reported in a separate IEC Technical Report. Based on the experience gained on this immunity test method, the adoption of a similar test to be applied for IEC 61547, the immunity standard for lighting equipment, will be considered.

[1] Numbers in square brackets refer to the Bibliography.

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EQUIPMENT FOR GENERAL LIGHTING PURPOSES – EMC IMMUNITY REQUIREMENTS –

Part 1: Objective light flickermeter and voltage fluctuation immunity test method

1 Scope

This part of IEC 61547 describes an objective light flickermeter, which can be applied for the following purposes:

– measuring the intrinsic performance of all lighting equipment without the application of voltage fluctuations in terms of illuminance flicker; during this measurement, the lighting equipment is supplied with a stable mains;

– testing the immunity performance of lighting equipment against (unintentional) voltage fluctuation disturbance on the AC mains in terms of illuminance flicker; during this test a set of defined voltage fluctuations are applied to the AC mains and the immunity of the lighting equipment to the disturbance is determined.

Apart from the above two purposes, the immunity performance of lighting equipment can also be tested against intentional voltage fluctuation on the AC mains arising for example from mains signalling. This is however not described in further detail in this document.

NOTE 1 IEC 61000-4-13:2015 [24] provides guidance regarding test levels and frequencies for mains signalling.

The object of this document is to establish a common and objective reference for evaluating the performance of lighting equipment in terms of illuminance flicker. Temporal changes in the colour of light (chromatic flicker) are not considered in this test.

This method can be applied to lighting equipment which is within the scope of IEC technical committee 34, such as lamps and luminaires, intended for connection to a low voltage electricity supply. Independent auxiliaries such as drivers can also be tested by application of a representative light source to that auxiliary.

The objective light flickermeter and voltage fluctuation immunity method described in this document are based on the IEC 61000-3-3 standard for voltage fluctuation limits and the flickermeter standard IEC 61000-4-15.

The objective light flickermeter described in this document can be applied to objectively assess flicker of lighting equipment that is powered from any type of source, AC mains, DC mains, battery fed or fed through an external light level regulator. The specific voltage fluctuation immunity test method described in this document applies to lighting equipment rated for 120 V AC and 230 V AC, 50 Hz and 60 Hz.

NOTE 2 The principle of the method can be applied for other nominal voltages and frequency ratings.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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IEC 61000-3-3:2013, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection*

IEC 61000-4-15:2010, *Electromagnetic compatibility (EMC) – Part 4-15: Testing and measurement techniques – Flickermeter – Functional and design specifications*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61000-3-3 and IEC 61000-4-15 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
flicker
perception of visual unsteadiness induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a static observer in a static environment

Note 1 to entry: The fluctuations of the light stimulus with time include periodic and non-periodic fluctuations and can be induced by the source itself, the power source or other influencing factors.

[SOURCE: CIE TN 006:2016]

3.1.2
flickermeter
instrument designed to measure any quantity representative of flicker

[SOURCE: IEC 60050-614:2016, 614-01-30]

3.1.3
voltage flickermeter
instrument which is designed to measure any quantity representative of flicker resulting from mains voltage fluctuations

Note 1 to entry: Specifications of the voltage flickermeter can be found in IEC 61000-4-15.

3.1.4
illuminance
quotient of the luminous flux $\mathrm{d}\Phi_\mathrm{v}$ incident on an element of the surface containing the point, by the area $\mathrm{d}A$ of that element

Equivalent definition. Integral, taken over the hemisphere visible from the given point, of the expression $L_\mathrm{v}\cdot\cos\theta\cdot\mathrm{d}\Omega$ where L_v is the luminance at the given point in the various directions of the incident elementary beams of solid angle $\mathrm{d}\Omega$, and θ is the angle between any of these beams and the normal to the surface at the given point

$$E_\mathrm{v} = \frac{\mathrm{d}\Phi_v}{\mathrm{d}A} = \int_{2\pi\ \mathrm{sr}} L_\mathrm{v}\cdot\cos\theta\cdot\mathrm{d}\Omega$$

Note 1 to entry: Illuminance is expressed in lx or $\mathrm{lm\cdot m^{-2}}$.

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[SOURCE: IEC 60050-845:1987, 845-01-38]

3.1.5
light flickermeter
instrument designed to measure flicker resulting from temporal changes in the intensity of the light in an objective way

Note 1 to entry: The light flickermeter is based on the IEC 61000-4-15 specifications.

3.1.6
threshold of flicker irritability
maximum value of a fluctuation of luminance or of spectral distribution which gives rise to a flicker tolerated without discomfort by a specified sample of the population

[SOURCE: IEC 60050-161:1990, 161-08-16]

3.1.7
short-term flicker indicator
P_{st}
measure of flicker evaluated over a specified time interval of a relatively short duration

Note 1 to entry: The duration is typically 10 min, in accordance with IEC 61000-4-15.

Note 2 to entry: The alternative term "short term flicker severity" is used in IEC 61000-3-3 and IEC 61000-4-15.

[SOURCE: IEC 60050-161:1990, 161-08-18, modified – Note 2 has been added.]

3.2 Abbreviated terms

AC	alternating current
CFL	compact fluorescent lamp
CIE	Commission Internationale de l'Éclairage
cpm	changes per minute
DC	direct current
EUT	equipment under test
EMC	electromagnetic compatibility
Hz	hertz
IEEE	Institute of Electrical and Electronics Engineers
kHz	kilohertz
LED	light emitting diode
ms	millisecond
RMS	root mean square
SSL	solid state lighting
V	volt
W	watt

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3.3 Symbols

α	multiplication factor
C_A	gain of the light amplifier
d	relative voltage change
d_E	relative change of the rectangular modulation of the illuminance
d_r	relative change of the 100 Hz-illuminance ripple
ΔL	instantaneous total light variation after a voltage fluctuation
Δu	instantaneous total voltage variation after a voltage fluctuation
ΔU	total voltage variation of the half-period RMS value after a voltage fluctuation
f	mains frequency (50 Hz or 60 Hz)
f_m	modulation frequency
L	light
m	modulation index
%	percent
pp	percentage point
P_{inst}	instantaneous flicker sensation
P_{st}	short-term flicker indicator
P_{st}^{LM}	flicker metric of the illuminance of an EUT without the application of voltage fluctuations and measured with a light flickermeter
$P_{st}^{LM}(I)$	flicker metric of the illuminance of an EUT with the application of voltage fluctuations and measured with a light flickermeter
$P_{st}^{LM}(C)$	flicker metric of the illuminance of the combination of a light source and a dimmer measured with a light flickermeter
P_{st}^{V}	flicker metric of the supply voltage measured with a voltage flickermeter
$P_{st}^{V}(N)$	flicker metric of the noise level from an unmodulated supply voltage measured with a voltage flickermeter
s	complex Laplace variable
$\hat{u}$	amplitude of the mains voltage
$u(t)$	mains voltage signal
$u_E(t)$	output voltage of the light sensor amplifier
T_m	modulation period
T_{test}	period of time over which the illuminance is measured during application of the voltage fluctuation
U	half-period RMS-value

4 General

The immunity of lighting equipment to voltage fluctuations may be tested by applying specific types and levels of voltage fluctuations to the mains, in accordance with the short-term flicker indicator $P_{st} = 1$ curve for the reference incandescent lamp of 60 W specified in IEC 61000-3-3. In this way, the full EMC approach is applied for flicker, i.e. voltage fluctuations caused by equipment connected to the grid are limited by the voltage fluctuation emission test of IEC 61000-3-3, while the level of flicker immunity of lighting equipment

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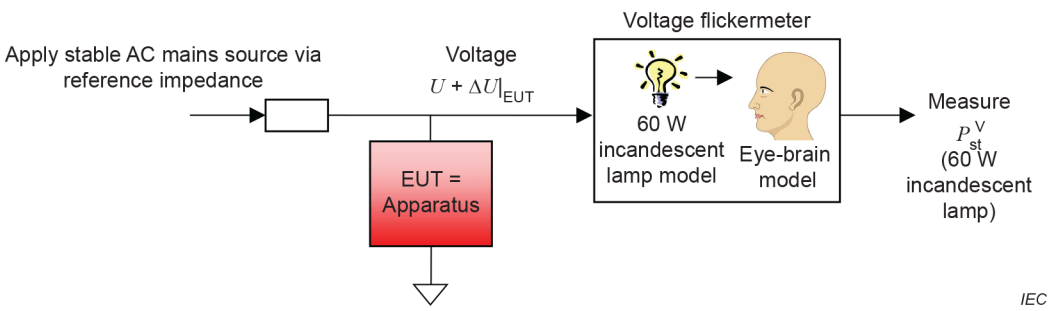
against these P_{st}^{V} = 1 voltage fluctuations is tested using the method specified in this document (see Figure 1).

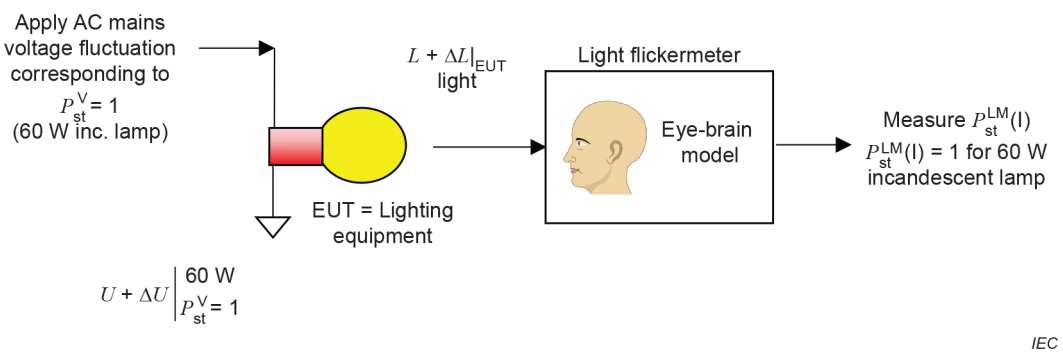
During the test, the supply voltage is modulated with a fluctuation of P_{st}^{V} = 1 which is extracted from the threshold of the flicker irritability curve. The luminous intensity variation of the lighting equipment is measured and recorded. A light flickermeter is applied to measure the value of the metric which is denoted by $P_{st}^{LM}(I)$, which indicates that the test is carried out with the application of voltage fluctuations and the letter I stands for immunity. Further details of the voltage fluctuations can be found in Table 1.

A flicker measurement can also be performed in order to determine the intrinsic flicker performance of the lighting equipment. During this test, a stable mains source (see 6.2) is used (i.e. no voltage fluctuations are applied). Similar to the above, the luminous intensity variation of the lighting equipment is measured and recorded. A light flickermeter is applied to measure the value of the metric which is denoted by P_{st}^{LM}.

NOTE In principle, flicker perfomance tests can be applied to an individual product as well as to test the flicker performance of installations in actual applications (in-situ). However, the latter in-situ testing is much more prone to measurement uncertainties due to various influence quantities such as ambient light, light modulations from other light sources or daylight or moving subjects and (undefined/irregular) voltage fluctuation on the network. Therefore, P_{st}^{LM} measurements are normally done at product level. The TLA performance of an actual application environment of multiple light sources is generally better than the TLA performance of a single light source due to the averaging out of the light modulation from the different light sources. Note that the flicker immunity test against voltage fluctuations ($P_{st}^{LM}(I)$) cannot be performed in-situ.



a) Voltage fluctuation emission test in IEC 61000-3-3, using the IEC voltage flickermeter in IEC 61000-4-15



b) Voltage fluctuation immunity test specified in this document

Figure 1 – Full EMC approach for mains voltage fluctuations

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5 Light flickermeter

For an objective assessment of flicker due to low-frequency light modulation, the flickermeter specified in Annex A is used. Additional requirements for this light flickermeter are given in 7.3, 7.4, 7.5 and 7.6.

This light flickermeter can be applied to objectively assess the flicker of lighting equipment that is powered from any type of source, AC mains, DC mains, battery powered or powered through an external light level regulator. In this document, specific mains voltage disturbance signals are given in Clause 6 for 120 V AC and 230 V AC, 50 Hz and 60 Hz networks.

6 Voltage fluctuation disturbance signal

6.1 General

The immunity test against voltage fluctuations is carried out in accordance with the test method specified in Clause 7. The disturbances are rectangular amplitude modulations that are applied on the AC mains.

The mains signal is amplitude modulated with rectangular signals with frequencies between approximately 0,3 Hz and 40 Hz. For the rectangular modulated mains signal $u(t)$, the following Equation (1) applies:

$$u(t) = \hat{u} \cdot \sin(2\pi f t) \cdot \{1 + m \cdot \text{signum}\,(\sin(2\pi f_m t))\} \tag{1}$$

where

$\hat{u}$ is the amplitude of the mains voltage;

f is the mains frequency;

m is the modulation index;

signum(x) = the signum function, signum(x) = 1 for $x > 0$
signum(x) = 0 for $x = 0$
signum(x) = –1 for $x < 0$

f_m is the modulation frequency = $1/T_m$.

Furthermore, the half-period RMS value U of the unmodulated mains signal can be written as:

$$U = \hat{u} / \sqrt{2} \tag{2}$$

In IEC 61000-4-15, the relative voltage change d is applied:

$$d = \Delta u / \hat{u} = \Delta U / U\,, \tag{3}$$

for rectangular amplitude modulation with modulation frequencies $< f$

where

Δu is the instantaneous total voltage variation after a voltage fluctuation;

ΔU is the total voltage variation of the half-period RMS value after a voltage fluctuation.

For a rectangular modulated mains signal with modulation index m the relative voltage change d is:

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