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Abstract: The standard IEC 61000-4-15 establishes the design specifications to measure the annoyance produced by flicker. This instrument is based on the working principles and the response to input voltage variations of an incandescent lamp, which was taken as the reference lamp for the design. However, nowadays new lighting technologies are being adopted worldwide and the incandescent lamp has fallen into disuse. With the purpose of characterizing the sensitivity to voltage fluctuations of new modern lamps an adapted flickermeter has been designed. This tool uses as input the illuminance signals registered from the different lighting technologies. This paper describes the implementation of an illuminance flickermeter as well as its functional verification according to the type tests described in the new edition of the IEC 61000-4-15 standard.

Keywords: Flicker, Power quality, Flickermeter, IEC 61000-4-15, voltage fluctuation.

Type Testing of a Highly Accurate Illuminance Flickermeter

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Abstract

The standard IEC 61000-4-15 establishes the design specifications to measure the annoyance produced by flicker. This instrument is based on the working principles and the response to input voltage variations of an incandescent lamp, which was taken as the reference lamp for the design. However, nowadays new lighting technologies are being adopted worldwide and the incandescent lamp has fallen into disuse.

With the purpose of characterizing the sensitivity to voltage fluctuations of new modern lamps an adapted flickermeter has been designed. This tool uses as input the illuminance signals registered from the different lighting technologies. This paper describes the implementation of an illuminance flickermeter as well as its functional verification according to the type tests described in the new edition of the IEC 61000-4-15 standard.

Index Terms

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I. Introduction

Fluctuations in the brightness of a light source are caused by voltage fluctuations in the power system network supplying the lamps. The sensation experimented by the human visual system due to changes in the illumination intensity is known as flicker, and may lead to complaints from utility customers.

The flicker annoyance assessment is carried out by a flickermeter which, using the supply voltage as an input, quantifies the level of discomfort by means of the short-time flicker severity, P_{st}. The IEC 61000-4-15 [1] standard establishes the functional and design specifications for the flickermeter, as well as the performance tests to evaluate its implementation and the type testing of the instrument. The IEC flickermeter was built based on the leading lighting technology at that time, the 60 W incandescent lamp, and hence the characterization of this kind of light source is included in the design of this measurement tool.

Nowadays, the incandescent lamp has fallen into disuse and new lighting technologies are being adopted worldwide which leads to consider the effectiveness of the IEC flickermeter. Some studies indicate that new lighting technologies seem to be less sensitive to flicker than incandescent lamps [2]–[4]. However, international organizations for standardization like CIGRE WG C4.108 [5] addressed the need of studying the influence of the new lighting technologies on the new edition of the IEC 61400-4-15, IEC 61000-3-3 [6] and IEC 61000-3-11 [7], as well as the standards which limit the emission of flicker. Several studies carried out in response to this necessity, have evidenced the fact that some of these new lamps present a higher sensitivity to flicker than that of the incandescent lamp [8], [9].

Considering the different responses among the new lamps, we can think about a tool valid for any kind of lighting technology providing a proper analysis of the influence of the new lamps on flicker generation. For that purpose an adapted flickermeter must be used, based on both the illuminance input and the specifications described in the IEC 61000-4-15 standard. Other studies have already designed this adapted flickermeter and used it for the comparison of different lighting technologies [10]. Furthermore, this new tool can be very appropriate when analysing the sensitivity to flicker of the lamps under complex fluctuations, such as rectangular fluctuations, and even to study the sensibility to flicker under real recorded signals. With this aim, the illuminance flickermeter should be based on a very accurate implementation. The verification of the accuracy should be guaranteed through the functional tests included in the new edition of the standard. This work presents the design of a new adapted illuminance flickermeter and its functional verification according to the different new tests detailed in the new edition of the IEC flickermeter standard of 2010. Specifically, Section II briefly introduces the IEC 61400-4-15 standard, describing the IEC flickermeter and detailing the type tests used for its verification. Section III describes the design of the illuminance flickermeter and the results of its verification, by means of the type tests of the standard, are presented in Section IV. Conclusions are stated in Section V.

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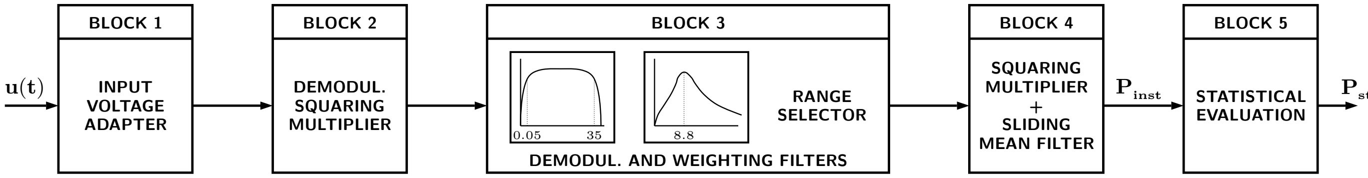


Fig. 1. Block diagram of the IEC flickermeter according to IEC 61000-4-15 [1].

II. Description of the IEC Flickermeter

This section introduces the specifications of the instrument defined by the IEC standard and the operational tests which define the way to test the accuracy of the output of a flickermeter.

A. Design specifications

The IEC 61000-4-15 standard defines the design specifications of a flickermeter following the block diagram represented in Figure 1. In the design of this flickermeter a 60 W incandescent lamp was assumed and consequently in some of the diagram blocks the performance characteristics of this lamp are included. *a) Block 1: Input Voltage Adaptor*

In this block the input voltage $u(t)$ is scaled to an internal reference value to make flicker measurements independent of the input voltage level. For this purpose, the RMS values of the input voltage are processed through a first order low-pass resistance/capacitance filter with a time constant of 27,3 seconds.

b) Block 2: Quadratic Demodulator

The scaled input voltage is demodulated by means of a squaring multiplier simulating the behavior of the lamp.

c) Block 3: Demodulation and Weighting Filters

This block comprises three cascaded filters. The first two filters complete the demodulation process and consist of a first-order high-pass filter (3-dB cut-off frequency $f_{\text{co}} = 0.05$ Hz) and a sixth-order low-pass Butterworth filter (3-dB cut-off frequency $f_{\text{co}} = 35$ Hz for 50-Hz systems). The third filter is a band-pass filter that models the behavior of the lamp-eye system and it is characterized by the following transfer function:

$$H(s)_{\text{lamp-eye}} = \frac{k\omega_1 s}{s^2 + 2\lambda s + \omega_1^2} \cdot \frac{1 + \frac{s}{\omega_2}}{(1 + \frac{s}{\omega_3})(1 + \frac{s}{\omega_4})}, \qquad (1)$$

where $k = 1.74802$, $\lambda = 2\pi 4.05981$, $\omega_1 = 2\pi 9.15494$, $\omega_2 = 2\pi 2.27979$, $\omega_3 = 2\pi 1.22535$ and $\omega_4 = 2\pi 21.9$.

These filters eliminate the dc component and strongly attenuate the frequency components above 100 Hz.

d) Block 4: Non-linear Eye-Brain Response

This block implements an eye-brain model including a squaring multiplier that simulates the nonlinear eye-brain response, followed by a sliding mean filter that accounts for the perceptual storage effects in the brain. This filter is a first-order low-pass resistance-capacitance filter with a time constant of 300 ms. The output of Block 4 represents the instantaneous flicker sensation P_{inst}. The reference human flicker perceptibility threshold corresponds with a value of $P_{\text{inst}} = 1$ and the flickermeter must be adjusted to obtain this value when a sinusoidal fluctuation of frequency $f_m = 8.8$ Hz and a relative amplitude of $\frac{\Delta V}{V} = 0.25\%$ affects the supply voltage.

e) Block 5: Statistical Evaluation

In this block the sort time flicker severity, P_{st}, is calculated over a time period (usually 10 min) by using the percentiles obtained from the cumulative probability distribution of the instantaneous flicker sensation.

We designed a complete digital Matlab implementation of a reference voltage flickermeter according to IEC 61000-4-15 in order to use its results as the reference values for our illuminance flickermeter verification. The correct implementation and proper performance of the reference voltage flickermeter has been successfully tested in several previous studies [11]–[13].

B. Type Tests

The IEC 61000-4-15 standard defines a number of tests, composed of different input voltage characteristics, in order to assess the flickermeter performance and the accuracy of its results. These tests allow to classify the instrument in 3 different classes: F1, F2 and F3. Each of these tests is briefly detailed below and summarized in Table I.

a) Test 1: Sinusoidal and rectangular voltage changes

The aim of this test is to check the response characteristic of the filters and scaling parameters of the flickermeter. The output of this test is the maximum value of the instantaneous flicker sensation $P_{\text{inst,max}}$ which has to be 1.00 with a tolerance of $\pm 8\%$. Several test points are detailed with a range of fluctuation frequencies from 0.5 Hz to 40 Hz.

b) Test 2: Rectangular voltage changes

TABLE I
SUMMARY OF THE TEST SPECIFICATIONS FOR THE FLICKERMETER.

Test	Test voltage characteristics	Test output	Flickermeter classes		
1	Sinusoidal / rectangular voltage changes.	P_{inst}	F1	F2	F3
2	Rectangular voltage changes and performance testing.	P_{st}	F1	F2	F3
3	Frequency changes.	P_{inst}	F1		
4	Distorted voltage with multiple zero crossings.	P_{inst}	F1		
5	Harmonics with side band.	P_{inst}	F1		
6	Phase jumps.	P_{st}	F1		
7	Rectangular voltage changes with duty ratio.	P_{st}	F1	F2	

TABLE II
TEST 3 SPECIFICATION FOR A 230 V-LAMP.

System Frequency (Hz)	Changing Frequency (Hz)	Changing Voltage (V)
50	49.75	230.000
	50.25	228.812

The main objective is to test the statistical evaluation algorithms. The P_{st} must be analysed, which has to be 1.00 with a tolerance of $\pm 5\%$ for a set of 7 frequencies of rectangular voltage fluctuations.

c) Test 3: Combined frequency and voltage changes

For a system frequency of 50 Hz and with a 230-V lamp, two test points at different frequency are defined. Both frequencies and the amplitude of the test voltage are changed in 4 second intervals at zero crossing of the voltage. This test is performed to analyse the measuring circuit. The observed $P_{\text{inst,max}}$ has to be 1.00 with a tolerance of $\pm 8\%$. The specifications of this test are detailed in Table II.

d) Test 4: Distorted voltage with multiple zero crossing

The distorted voltage is formed by the fundamental voltage U and the harmonic levels according to Table III. All the harmonics have a 180º phase shift with respect to the 50 Hz fundamental. This voltage is then sinusoidally modulated at 8.8 Hz with a modulation depth of 0.25%. The objective is to check the stability of the input control circuit. In this test the $P_{\text{inst,max}}$ has to be 1.00 with a tolerance of $\pm 8\%$.

e) Test 5: Bandwidth test using harmonic and inter-harmonic side band modulation

Two voltages with frequencies that are 10 Hz apart (f_ν, $f_i = f_\nu - 10$ Hz) are superimposed to the mains voltage. The frequency pairs f_ν and f_i are increased in steps of 50 Hz to establish the maximum bandwidth of the flickermeter. The highest frequency $f_{\nu,\text{max}}$ for which $P_{\text{inst,max}} = 1$ with a tolerance of $\pm 8\%$ is the input bandwidth of the flickermeter. The standard established that the maximum frequency $f_{\nu,\text{max}}$ shall be at least 450 Hz and the minimum frequencies to start with the test must be $f_i = 140$ Hz and $f_\nu = 150$ Hz, both with a relative voltage amplitude $\frac{U_i}{U} = 3.611\%$.

f) Test 6: Phase Jumps

A series of phase jumps are generated at the positive zero crossing after 1 min, 3 min, 7 min and 9 min ($\pm 10\%$s) after the beginning of a 10 min observation period. The phase jump angles used are $\Delta\beta = \pm 30$ and $\Delta\beta = \pm 45$. This test is performed to analyse the stability of the input control circuit, the input bandwidth and the statistical evaluation algorithms. The observed P_{st} has to be according to Table IV with a tolerance of $\pm 5\%$.

TABLE III
TEST 4 SPECIFICATION FOR DISTORTED VOLTAGE WITH MULTIPLE ZERO CROSSINGS.

Harmonic order ν	3	5	7	9	11	13	17	19	23	25	29	31
U_ν % of U	5	6	5	1.5	3.5	3.0	2.0	1.76	1.41	1.27	1.06	0.97

TABLE IV
TEST 6 SPECIFICATION FOR PHASE JUMPS FOR A 230 V-LAMP IN 50 HZ - SYSTEM .

Phase jump angle $\Delta\beta$	$\mathbf{P_{st}}$
±30	0.913
±45	1.060

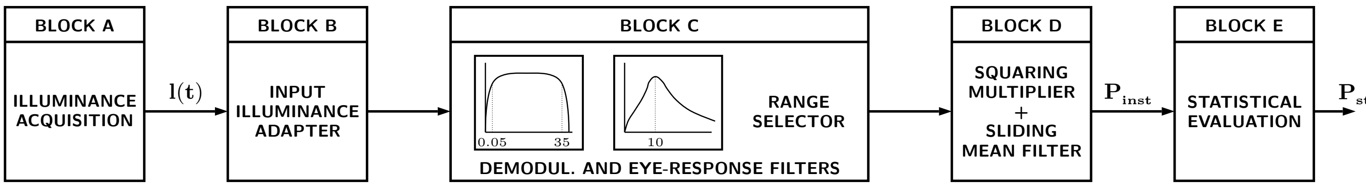


Fig. 2. Block diagram of the adapted illuminance flickermeter.

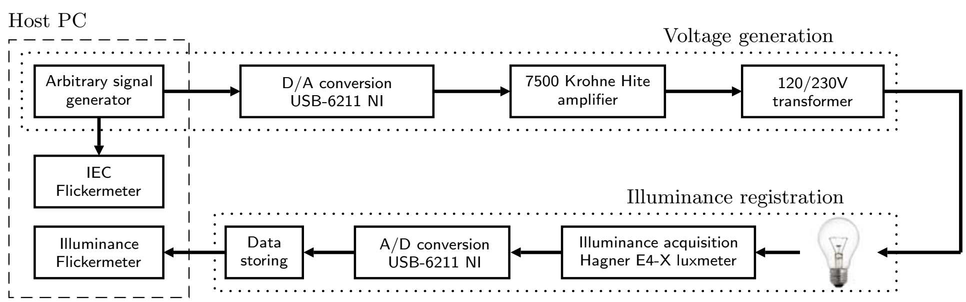


Fig. 3. Scheme of the generation and measurement system.

g) Test 7: Rectangular voltage changes with 20% duty cycle

The voltage U is rectangularly modulated at a rate of 28 Hz and a duty cycle of 20%, i.e. in a 60 seconds period the signal voltage spends 12 seconds at one level and 48 seconds at the other level. In a 50 Hz-system a voltage fluctuation of 1.418% must be applied being the output of this test the $P_{\text{st}} = 1.00$ with a tolerance of $\pm5\%$. The aim of this test is to check the statistical evaluation algorithms.

III. DESIGN OF AN ILLUMINANCE FLICKERMETER

An illuminance flickermeter is a powerful tool to measure the sensibility of any type of lamp. With this purpose, a digital Matlab illuminance flickermeter has been designed and implemented. The IEC voltage flickermeter analyses the flicker phenomenon in terms of the voltage fluctuations. However, this adapted flickermeter provides a P_{st} value by means of the illuminance signal recorded from the lamp. Consequently, in the design of the illuminance flickermeter the blocks of the IEC voltage flickermeter related with the response of the lamp need to be adapted. This implied the elimination of the quadratic demodulation (Block 2), as well as the modification of the weighting filter (Block 3). Figure 2 shows the adapted diagram of the new illuminance flickermeter.

A. Block A: Illuminance Acquisition

Firstly, it is needed to acquire and record the illuminance signal which will be later used as the input signal of the illuminance flickermeter. Figure 3 shows the lay-out of the experimental setup used to perform the experiments.

First, for all the tests, we registered the illuminance produced by the incandescent lamp when applying to it the corresponding analytically generated voltage signal, at a sampling rate f_s of 100 kHz. The digital output was converted to an analog signal by a D/A converter (USB-6211 National Instruments). The analog signal was then amplified to 230 V by a 7500 Krohne Hite Amplifier (75 W, from DC to 1 MHz) and an AC/AC transformer. This signal was applied to the lamp, which was inside a closed white box, where we also had the light sensor. In order to measure the illuminance level in luxes, this sensor was connected to a luxmeter (Luxmeter Hagner E4-X) whose spectral sensitivity closely relates to the visibility curve of the CIE (International Commission on Illumination) standard observer. The luxmeter provided an analog output signal, which represents the illuminance, that was then digitalized by the A/D converter (USB-6211 National Instruments) at 10 kHz and 16 bits per sample and registered by the PC.

B. Block B: Input Illuminance Adaptor

The input illuminance $l(t)$ is scaled to an internal reference value to make flicker measurements independent of the input illuminance level. For this purpose, the average values of the input illuminance are processed through a first order low-pass resistance/capacitance filter with a time constant of 27,3 seconds, the same filter of the IEC voltage flickermeter. For the digital implementation the bilinear transformation and a configurable sampling rate f_s has been used.

C. Block C: Demodulation and Weighting Filters

This block comprises three cascaded filters. The first two filters complete the demodulation process, being the same as the ones used in the IEC voltage flickermeter. In this first stage the objective is to suppress the dc component and strongly attenuate the component at twice the mains frequency. The lamp-eye weighting curve must be converted into the eye weighting curve since the lamp effects are assumed in Block A. Therefore, the third filter is a band-pass system that models only the eye response system. The analog response of this filter can be obtained by means of the characteristic curve of an incandescent lamp and the lamp-eye weighting curve as follows:

$$H(s)_{\text{lamp-eye}} = H(s)_{\text{eye}} \cdot H(s)_{\text{lamp}} \tag{2}$$

$$H(s)_{\text{eye}} = \frac{H(s)_{\text{lamp-eye}}}{H(s)_{\text{lamp}}} \tag{3}$$

The transfer function representing the eye response can thus be obtained using the transfer function of the lamp-eye weighting filter (1) and the corresponding transfer function of the incandescent lamp. Firstly the gain curve of the incandescent lamp is calculated by supplying the lamp with voltage fluctuations of modulating frequencies from $f_m = 1$ Hz to $f_m = 35$ Hz in steps of 1 Hz and with relative voltage amplitudes of $\frac{\Delta V}{V} = 1\%$. Using the same measurement system detailed in Block A, the illuminance signals are recorded, obtaining the gain curve in function of the modulation frequency as follows:

$$Gain = \frac{\Delta L/L}{\Delta V/V}(f), \tag{4}$$

where $\Delta L/L$ represents the relative amplitude of the illuminance fluctuation. The incandescent lamp transfer function is a first order low pass filter having the following form:

$$H(s) = \frac{a_o}{s + b_o} \tag{5}$$

We can obtain the values of the coefficients a_o and b_o since we know the frequency response of the lamp $Gain = |H(f)|$ as follows:

$$|H(f)|^2 = \frac{a_o^2}{(2\pi f)^2 + b_o^2} \tag{6}$$

We have a system equation with 2 variables which can be easily solved using the values for two frequencies inside the band of 35 Hz of the gain curve. In this way, the transfer function of the lamp is represented as follows:

$$H(s)_{\text{lamp}} = \frac{55.1465}{s + 54.7874} \tag{7}$$

Finally, the transfer function of the eye can be obtained from (1) and (3).

$$H(s)_{\text{eye}} = \frac{10^{-}2(0.0070s^3 + 0.4851s^2 + 5.5089s)}{(10^{-4}s^3 + 0.0061s^2 + 0.2766s + 1.8128)} \tag{8}$$

In Figure 4 the experimental sensitivity curve of the incandescent lamp and the frequency responses of the designed lamp filter, the weighting lamp-eye filter and the calculated eye filter are represented.

The digital implementation of all the filters of Block C is made according to the bilinear transformation. The first two filters are designed with a configurable sampling rate f_s. At the output of the low-pass demodulation filter a decimation process is performed to allow a sampling rate of f_p in the following blocks. In this way, the third filter is then designed for a sampling frequency of f_p.

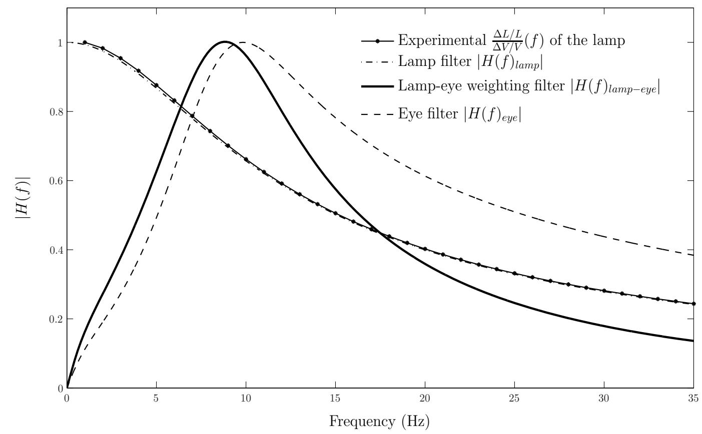


Fig. 4. Frequency response of the filters composing the flickermeter.

D. Block D: Non-linear Eye-Brain Response

This block is the same as the one presented in the IEC voltage flickermeter and is implemented by using the bilinear transform and a sampling rate of f_p. As in the voltage flickermeter, the adjustment of the illuminance flickermeter must be done based on the illuminance produced by an incandescent lamp supplied by a sinusoidal fluctuation of $f_m = 8.8$ Hz and a relative amplitude of the voltage fluctuation of $\frac{\Delta V}{V} = 0.25\%$ providing $P_{\text{inst,max}} = 1$. Nevertheless, when comparing the P_{inst} signal of the IEC flickermeter with the one of the illuminance flickermeter we noticed that the one of the illuminance flickermeter is affected by a zero mean noise, making it difficult to find the representative maximum value of P_{inst}. Therefore, the procedure of obtaining a value of $P_{\text{inst,max}}$ to adjust the new flickermeter must be changed. Firstly, using a peak detection algorithm the position of the relative maximum values of the P_{inst} signal are calculated. Now, the criteria ($P_{\text{inst,max}} = 1$) for the adjustment of the flickermeter is based on the average of the relative maximum values of P_{inst}.

E. Block E: Statistical Evaluation

The statistical procedure is the same as the one defined in the IEC 61000-4-15 standard. However, to avoid errors coming from the classification process in terms of number of classes, type of classification or type of interpolation between the classes, our flickermeter works offline, and it is possible to calculate the percentiles of the statistical procedure for the complete set of samples of the instantaneous flicker sensation, with the accuracy provided by Matlab.

IV. Results of the Illuminance Flickermeter Verification

According to the tests described in Section II-B all the corresponding voltage signals have been generated in order to check the accuracy and classify the instrument. Moreover, and with the purpose of certifying the validity of the verification, these signals have been analysed by means of the illuminance flickermeter and also by the voltage flickermeter which has already been used in other works [11]–[13]. Both instruments work using a $f_s = 10000$ Hz and $f_p = 1000$ Hz. All the results obtained are shown below.

A. Test 1

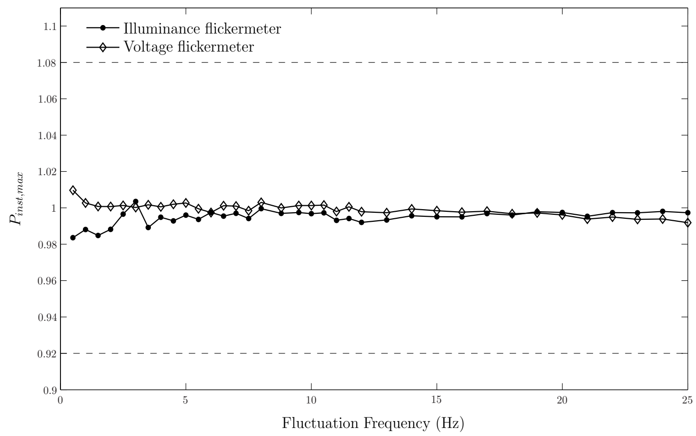
A number of test points characterized by sinusoidal and rectangular fluctuations are used in this test and their results are represented respectively in Figure 5(a) and Figure 5(b). Both figures show the $P_{\text{inst,max}}$ values of the illuminance flickermeter as well as the ones of the voltage flickermeter. Moreover, the valid range of the $P_{\text{inst,max}}$ values, delimited by the dashed lines, is also represented. As shown in both figures the illuminance flickermeter meets the requirements without differing too much from the results of the reference voltage flickermeter, being both inside the valid range.

B. Test 2

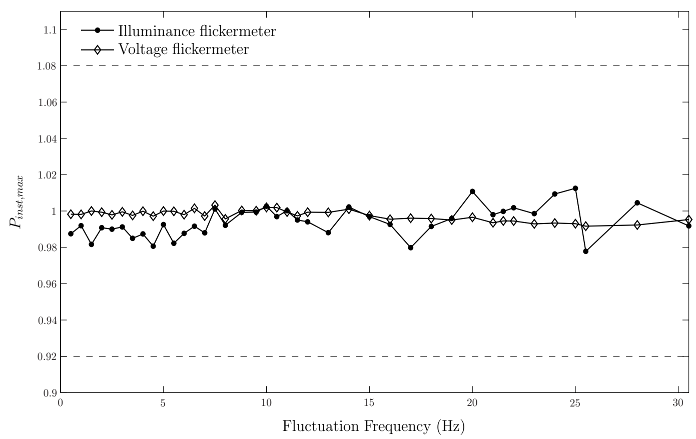
In Table V the results of the second test are detailed. The values of P_{st} obtained with the voltage and the illuminance flickermeter are shown as well as the percentage deviation with respect to the value of $P_{\text{st}} = 1$. The illuminance flickermeter keeps within this limit of $P_{\text{st}} = 1 \pm 5\%$ required by the standard.

C. Test 3

As it has already been detailed, for this test a value of $P_{\text{inst,max}} = 1 \pm 8\%$ is required. The illuminance flickermeter provided a value of $P_{\text{inst,max}} = 1.03$ with a deviation from $P_{\text{inst,max}} = 1$ of 0.94%. Furthermore, with the voltage flickermeter we obtained a value of $P_{\text{inst,max}} = 1.0157$ presenting an error of 1.57%. Therefore, in view of the results the illuminance flickermeter fully complies with the requirements.



(a)



(b)

Fig. 5. Test 1 results for sinusoidal (a) and rectangular fluctuations (b).

TABLE V
RESULTS FOR TEST 2.

Changes per Minute (CPM)	Voltage Flickermeter P_{st}	Voltage Flickermeter $\frac{\Delta P_{st}}{P_{st}}$ [1]	Illuminance Flickermeter P_{st}	Illuminance Flickermeter $\frac{\Delta P_{st}}{P_{st}}$ [1]
1	1.0063	0.63	0.9906	0.94
2	1.0081	0.81	0.9915	0.85
7	1.0086	0.86	0.9930	0.7
39	1.0003	0.03	0.9936	0.64
110	0.9986	0.14	0.9929	0.71
1620	0.9978	0.22	1.0026	0.26
4000	0.9882	1.18	1.0019	0.19

[1] Percentage deviation from $P_{\mathrm{st}} = 1$

D. Test 4

When analysing the results of this test, and using the illuminance flickermeter, a value of $P_{\mathrm{inst,max}} = 0.9972$ with an error of 0.28% was obtained. The voltage flickermeter provided a value of $P_{\mathrm{inst,max}} = 1.0003$ with an error of 0.03%. Taking into account the requirements of the test ($P_{\mathrm{inst,max}} = 1 \pm 8\%$) it can be concluded that the illuminance flickermeter also meets the requirements of this test.

E. Test 5

This test establishes that beginning with the modulating frequencies of $f_i = 140$ Hz and $f_\nu = 150$ Hz, and increasing them in steps of 50 Hz the highest frequency $f_{\nu,max}$ needs to be found for which $P_{\mathrm{inst,max}} = 1 \pm 8\%$. However, analysing the results from Table VI we can see how at low modulating frequencies, close to 150 Hz, the deviation of $P_{\mathrm{inst,max}}$ from

TABLE VI
RESULTS FOR TEST 5.

f_i/f_ν (Hz)	Voltage Flickermeter $P_{\text{inst,max}}$	$\frac{\Delta P_{\text{inst,max}}}{P_{\text{inst,max}}}$ [1]	Illuminance Flickermeter $P_{\text{inst,max}}$	$\frac{\Delta P_{\text{inst,max}}}{P_{\text{inst,max}}}$ [1]
140/150	0.9880	1.2	0.8258	17.42
190/200	0.9958	0.42	1.0005	0.05
240/250	1.0063	0.63	0.9746	2.54
490/500	0.9929	0.71	0.9967	0.33
990/1000	0.9972	0.28	0.9944	0.56
1990/2000	0.9840	1.6	0.9891	1.09
2990/3000	0.9960	0.4	0.9789	2.11
3990/4000	0.9881	1.19	0.9620	3.8
4490/4500	0.9110	8.9	0.9415	4.24

[1] Percentage deviation from $P_{\text{inst,max}} = 1$

TABLE VII
RESULTS FOR TEST 6.

Phase Jump Angle	Voltage Flickermeter P_{st}	$\frac{\Delta P_{\text{st}}}{P_{\text{st}}}$	Illuminance Flickermeter P_{st}	$\frac{\Delta P_{\text{st}}}{P_{\text{st}}}$
-30º	0.9139	0.0986[1]	0.8951	1.9606[1]
+30º	0.9106	0.2629[1]	0.9266	1.4896[1]
-45º	1.0626	0.2453[2]	1.0683	0.7830[2]
+45º	1.0563	0.3491[2]	1.0649	0.4623[2]

[1] Percentage deviation from $P_{\text{st}} = 0.913$
[2] Percentage deviation from $P_{\text{st}} = 1.060$

the desired value is too high whereas our illuminance flickermeter has no problem with much higher modulating frequencies. Therefore, our limitation is on the minimum value of f_i not on the maximum value of f_ν. When working with this low pair of modulating frequencies (140/150 Hz) some frequency components around 100 Hz appear in the illuminance signal. In the case of the voltage flickermeter these components are sufficiently attenuated by the combination of the demodulating filters and the lamp-eye weighting filter so that the bandwidth analysis can be started with these pair of frequencies. As it has been previously explained, in the illuminance flickermeter the lamp-eye weighting filter is substituted by the eye-filter which was not adjusted considering the attenuation of 100 Hz. A proper solution could be to design a new eye-filter with the same bandpass characteristic and with a greater attenuation in frequencies at twice the mains frequency.

F. Test 6

In this test, for a phase jump angle of ±30 a value of $P_{\text{st}} = 0.913 \pm 5\%$ is required and for a phase angle of ±45 the value changes to $P_{\text{st}} = 1.060 \pm 5\%$. The results are shown in Table VII and as in the other tests, the illuminance flickermeter has no problem meeting the requirements.

G. Test 7

In this case, the illuminance flickermeter provided a value of $P_{\text{st}} = 1.004$ and taking into account the requirements of this test ($P_{\text{st}} = 1 \pm 5\%$), we have an error of 0.4%. With the voltage flickermeter we had a value of $P_{\text{st}} = 0.9941$ with an error of 0.59%. Therefore, the illuminance flickermeter is also inside the valid range required by the standard.

V. CONCLUSIONS

Nowadays, the incandescent lamp has been replaced by the widespread use of new lighting technologies such as compact fluorescent lamps (CFL) and LED lamps. Taking into account that the voltage IEC flickermeter was designed solely according to the response of the incandescent lamp, it is important to study the sensitivity to flicker of these new types of lamps. We have designed an illuminance flickermeter, a measurement tool useful for the analysis of the sensitivity to flicker of any lighting technology as well as to check how the same real voltage fluctuations supplying different lamps would affect. The authors have proposed a digital implementation of an illuminance flickermeter and in order to test its accuracy the different type tests proposed in the new edition of the IEC 61000-4-15 standard have been performed. The illuminance flickermeter works based on illuminance signals, therefore a measurement setup was also implemented.

After checking all the results obtained from the different tests and according to the flickermeter classification detailed in Table I, it can be concluded that this implementation meets all the requirements of all the tests and it can be validated as a Class-F1 flickermeter.

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