# Low Cost Device For Light Flicker Measurement

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***Abstract-*** A new instrument for the evaluation of disturbances caused by variations in lamp voltage (*light flicker*) is proposed, based on light intensity measurements. Unlike current standard (IEC EN 61000-4-15), which determines flicker severity by filtering powering voltage measurements with a standard lamp model (230V/60W), the presented methodology includes the lamp itself in the measurement process, thus realizing an *objective* measurement of flicker. A testing station for the metrological characterization of the device has been implemented and measurements have been compared to a standard IEC flickermeter (Norma D6000). Thanks to its portability, the instrument can be used to measure light flicker over a wide range of environments spanning from home/office to industrial locations.

## I. Introduction

The most recent studies on lighting and illumination indicate that light modulation of luminous flux (*light flicker*) at invisible frequencies from conventional lighting may induce discomfort in humans. Yet no coherent theory has yet been proposed that can explain the phenomenon. Some researchers suggest that electric and magnetic fields of certain frequencies can interfere with the nervous system; however, others believe that hypersensitivity is a psychosomatic illness, and the syndrome has even been considered a type of hypochondria. Often, but not always, symptoms first appear while working in front of a computer's video screen or with fluorescent lamps. Thereafter, many patients experience hypersensitivity to AC cables and several other electrical devices.

Whatever the cause, the condition is a very serious handicap for those people who experience it. Many of the sufferers cannot work in an office, and some of them feel compelled to move to remote areas where they live in houses without electricity.

Preliminary findings made by different research groups indicate that light flicker at low frequencies plays a central role in this phenomenon. Most lamps fed by fluctuating voltage produce light flicker at frequencies that can influence the nervous system.

The physiological malaise caused by this phenomenon depends on the amplitude of the fluctuations, sequence of repetitive voltage variations, or the frequency spectrum and the duration of the disturbance. The effects can range from minor irritation to health risk. In fact, it has been shown that video games can cause epileptic seizures to some people prone to this disease due to the frequency of images that is below that used in movies. In the armed forces, a flicker frequency of 10 Hz is used to test future combat pilot candidates for nervous disorders. The levels of flicker that are normally encountered in an electrical network are generally very low. Nevertheless the malaise caused by them is not negligible particularly for two important domestic leisure activities, namely, reading and watching TV.

The perceptible visual sensitivity of a human being to light intensity variations of an incandescent lamp powered by and amplitude fluctuating voltage varies with the frequency and presents a maximum spectral response between 8 and 10 Hz at 0,3% voltage variations [1]; the upper frequency limit is 35 Hz (any frequency higher than this limit does not cause luminosity variations due to the thermal inertia of the tungsten filament). To better understand the flicker phenomenon, it is important to bear in mind that: a) human eye distinguishes variations of luminosity when their frequency is less than about 35 Hz; b) the sensitivity to these variations depends on the duration of these flashes: short flashes cause dominant flicker; c) flicker is more critical in lateral vision than in fovea (direct) vision; d) the intensity

of flicker sensation depends on the individual, the amount of ambient luminance, the activity of the subject, the amount of lit surface, and a little bit on the color of the lighting source.
The great impact produced by the light flicker phenomenon has led the International Standard Committees to fix very restrictive limits. Different working groups belonging to CIGRE, UIE, IEC, IEEE and universities are still discussing this topic [1], [2], [3], [4] in order to take into account the modern power system scenario.

## II. Light flicker phenomenon and its measurement via IEC flickermeter

The IEC has defined the standard instrument for the evaluation of flicker effect (usually named IEC flickermeter) [1]. The purpose of the flickermeter is to assess the level of severity of light flicker by measuring voltage fluctuations and then predicting the level of irritation based on known characteristics of a 230V/60W incandescent lamp and the human eye-brain chain. The output of a standard flickermeter is the instantaneous flicker sensation (P.U.), which is usually analysed statistically by means of the following formula that gives the *short term* flicker sensation indicator:

$$P_{st} = \sqrt{\begin{array}{l} 0.0314P_{0.1} + 0.0525P_{1s} + \\ 0.0657P_{3s} + 0.28P_{10s} + 0.08P_{50s} \end{array}}$$

being $P_{0.1}$, $P_{1s}$, $P_{3s}$, $P_{10s}$ and $P_{50s}$ the Instantaneous Flicker Sensation in Perceptibility Units that exceeds 0.1%, 1%, 3%, 10% and 50% of the observation interval, with the suffix *s* indicating smoothed values [1].

It is important to underline that the IEC flickermeter employs the quadratic demodulator reflecting the original choice of referring to incandescent lamps as the only voltage-luminous flux conversion system. It can be shown that different flickermeter implementations that fully meet the performance tests defined by the standard can still disagree significantly in some actual measurements. The reason of this disagreement can be found in the fact that the specifications contained in the standard were developed for analogical implementations and this leaves to the manufacturers of digital flickermeter a certain amount of design freedom. Moreover, the IEC test points are not very tight (for most of them a tolerance of 5% is allowed) because they were originally obtained by flickermeter simulations that, at the time, reproduced, more or less accurately, information derived empirically about flicker perception. Therefore, even a perfect implementation of all the processing blocks is not likely to meet the test points exactly. Finally, several new kinds of disturbances which can potentially be sources of light flicker (i.e., interharmonics) are nowadays present on the power network and the standard does not account for them.

The software and hardware implementation of test systems for flickermeter calibration needs very accurate and sophisticated instruments in order to meet the accuracy requirements of the standard [5], [6]. Moreover, it is important to underline that calibrating Power Quality measurement equipment may

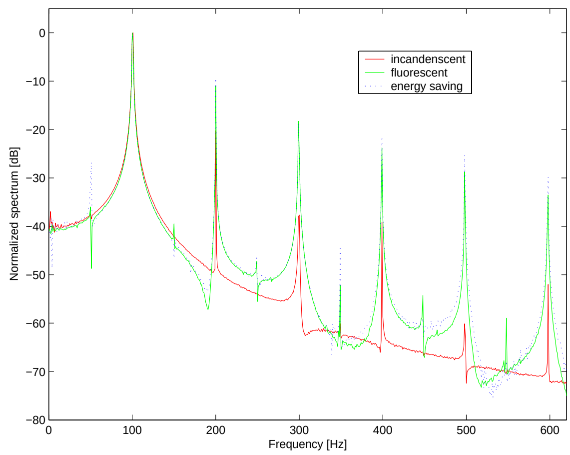


Figure 1 – Harmonic components of light intensity vs. lamp technology

have a legal status similar to other measurement equipment used for commercial purposes.

## III. Lamp technology

In earlier studies, the flicker phenomenon has been analyzed in terms of amplitude modulation. First, filament lamps were analyzed and luminous flux' fluctuation in response to supplying voltage

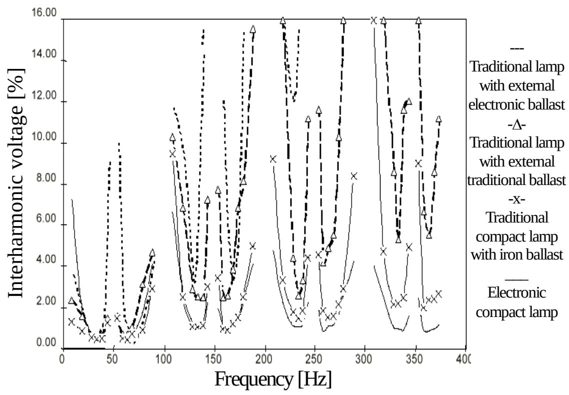


Figure 2 – Flicker perceptibility thresholds versus interharmonic frequencies.

modulations was clarified and modelled. It has recently been shown [4] that the voltage oscillation reflects on the luminous flux in a way depending on the lamp technology, and that in presence of interharmonic components in the supply voltage, light flicker can be observed both in filament and fluorescent lamps. However, the mechanisms and the involved frequency range, as well as the amplitudes, are quite different. Figure 1 shows e.g. the spectral content of lamp adopting different conversion systems powered by the same voltage.

With reference to filament lamps, it is possible to demonstrate that a single interharmonic tone can cause light flicker as an amplitude modulation because both produce similar oscillation in *rms* value of the supply voltage, which the luminous flux of filament lamps is sensible to. Since the *rms* value oscillations are less influenced by components over 100 Hz, initially attention was devoted to the frequency range from 0 Hz to 100 Hz.

With regards to fluorescent lamps, a great impact has been demonstrated in terms of light flicker also in the case of superimposed interharmonic components in supplying voltage over 100 Hz depending on their technology [6]. This is due to the fact that light flicker in these lamps is related to oscillation of peak value rather than *rms* value. Theoretical and flicker severity physiological experiments with human observers have been conducted. Figure 2 reports flicker perceptibility thresholds for different types of fluorescent lamps versus interharmonic frequency. Two types of lighting devices were tested: traditional lamps equipped with external ballast and compact lamps. Each technology has been tested with both traditional and electronic ballast. It can be noted that perceptibility curves for traditional lamps drop off quickly at higher frequencies and that interharmonics of the same amplitude at different frequencies produce different effects in terms of flicker. Electronic ballasts appear to be very sensitive between 30 and 70 Hz, and to better filter the interharmonic frequencies between 130 Hz and 170 Hz; they can even be considered insensitive to frequencies higher than to 170 Hz. However, compact electronic lamps remain sensitive to higher frequencies.

## IV. An *objective* flickermeter

It is important to underline that the standard IEC flickermeter assumes the incandescence lamp as the reference system for voltage-light conversion. In authors' belief this poses a strong limitation, which gives the main motivation for the novel approach for light flicker assessment and evaluation.

While standard IEC flickermeter (Norma D6000 in Figure 3) connects directly to the power line and determines the flicker sensation with reference to a standard 60W/230V lamp no matter the actual lamp used, the alternative device proposed here returns a parameter which is obtained from the luminous flux emitted by the lamp and therefore is much more objective as for the correspondence of such parameter with the flicker sensation suffered by the human eye. As a matter of fact, it is the lamp that is

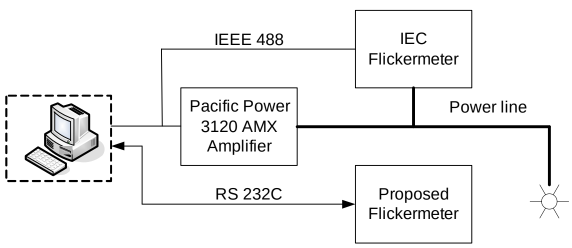


Figure 3 – Calibration setup for the objective flickermeter

tested for flickering, not the voltage powering it. Figure 3 also shows how the proposed flickermeter can be tested. A power source (Pacific Power 3120 AMX Amplifier) is used to generate a calibrated voltage signal to power a test lamp. A measuring device such as Norma D6000 is also attached to the power line, and both power source and flickermeter are connected though IEEE-488 bus cable to a central processing unit. The host PC receives both data from Norma D6000 – from which it determines the flicker sensation as per standard, – and signals from the *objective* flicker-meter through a serial RS 232C connection. The host then compares the two results and determines how different is the standard evaluation from the one obtained with the novel approach [8], [9].

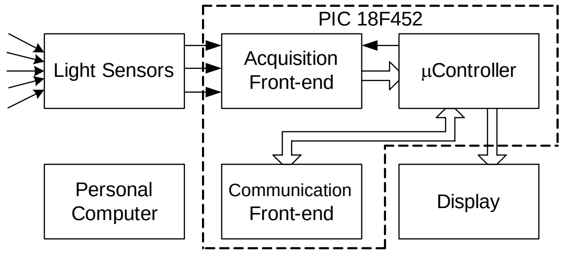

Figure 4 – Block diagram of proposed flickermeter

The electronics inside the proposed instrument is depicted in Figure 4. A light sensor acquires luminous flux and transduce it to a PIC-18F452 chip. This includes an acquisition front-end, a programmable microcontroller and a communication front-end. From the microcontroller a control signal departs which tells the acquisition device which light sensors to activate and acquire signals from.

The use of more than one sensor offers the capability of not only addressing the overall flicker sensation investigation but also to discriminate between different types of lamps by comparing output signals of each sensor. Certainly one of the sensors to be used is the one with a frequency response that matches that of the human eye, so that output signals resemble those flowing through the optical nerve from the eye to the brain. Commands to the microcontroller are sent by the host PC through the communication front-end which is also used to send signals and results back to the PC itself for further elaboration and analysis. The programmable controller is also equipped with a data bus to connect to an external display for local visualization and diagnostic purposes.

## V. Experimental results

Figure 5 shows experimental results obtained during calibration of the *objective* instrument through application of signals modulated by a sine wave with the calibration setup shown in Figure 3, using a 230V/60W standard lamp. The figure also shows the flicker sensation obtained by the standard flickermeter. Frequencies lying in the middle of the calibration range show a good agreement of the proposed device to acceptance criterion *P.U.* = 1 ± 5%, that is not matched instead in the low and high end

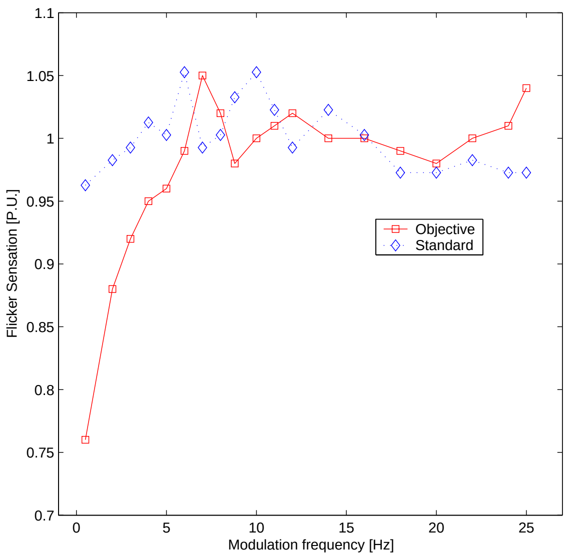

Figure 5 – Flicker sensation vs. modulation frequency
for standard and objective flickermeter

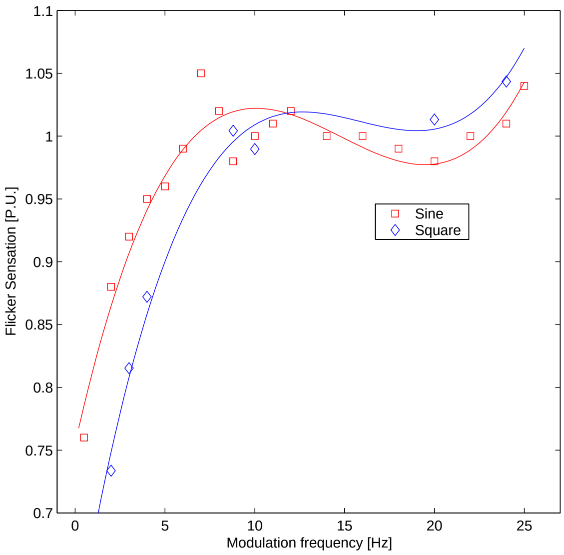

Figure 6 – Flicker sensation vs. modulation frequency
for sine and square modulating wave

of the interval. Though more investigations are being carried out, such behaviour is to be linked to the modifications introduced by excluding the lamp's transfer function in the lamp-eye-brain chain [10] and its substitution with the photodiode. In particular, the high-pass feature at high frequencies can be considered an effect of the suppression of the low-pass filter which us usually adopted as a model for the incandescent standard lamp.

Finally, Figure 6 shows the same calibration curve for two different signals, namely a sine and square modulating wave. It is noticeable that curves have a similar behaviour, illustrated by the third degree interpolating polynomial. This is a relevant feature which we can in principle profit of, because by introducing an appropriate equalizing filter that enhances the lower frequencies and attenuates the higher ones, we can try to make the response independent from frequency.

## VI. Conclusions

Voltage variations in light systems power lines are known to produce annoying fluctuation in luminous flux (light flicker). Different research groups indicate that light flicker at low frequencies plays a central role in this phenomenon. The main quantities influencing such physiological malaise are the amplitude of the fluctuations, sequence of repetitive voltage variations and the frequency spectrum and duration of disturbances.

To monitor this phenomenon a new measurement device has been proposed which is able to perform an *objective* evaluation of flicker annoyance. The main difference with existing devices is in that it measures variations of light intensity, not of voltage at lamp terminals thus not been dependent of a lamp model that may be different from the one being tested. Furthermore, thanks to its portability, light weight and ease of use, but mainly the capability of evaluating flicker sensations with a point resolution and taking into account full ambient conditions, it seems particularly suitable for measurement campaigns involving worker's welfare in both office and industrial environments.

Experimental results of calibration performed under standard condition and with the same signals adopted for calibrating IEC fickermeters show generally a good agreement of the proposed instrument with the acceptance criterion dictated by the standard. Where compliance is not met – i.e., for modulation frequencies lying in the low and high end of the calibration interval – the reason has been found in the substitution of reference 230V/60W lamp with the detecting photodiode.

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