Temporal Light Artefacts (Flicker)
A Quality Requirement for GSLs

FORTALECIMIENTO DE ESTÁNDARES DE EFICIENCIA ENERGÉTICA EN ILUMINACIÓN
Primera Reunión y Taller Presencial del Grupo Técnico de Eficiencia Energética (GTEE)

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1. Overview of the Problem
2. IEC Technical Reports
3. Products Tested
4. Requirements Proposed
Light Variation with Time

• Temporal variation in light output from a light source known as Temporal Light Modulation (TLM)

• TLM can have visual and non-visual effects on a person.

• The term for these effects, as defined by CIE, is Temporal Light Artefacts (TLA).

• There are three main situations where TLAs are visually perceivable.
Flicker

- Light source: stationary but varies in intensity or colour
- Observer’s eyes: not moving (i.e., without saccades)
- Illuminated object: stationary
  - Variation in light: above threshold of visual perception
  - Visual effect: light is flashing

http://bestanimations.com/HomeOffice/Lights/Bulbs/Bulbs.html
Stroboscopic Effect

Light source: stationary but varies in intensity or colour

Observer’s eyes: not moving (ie without saccades)

Illuminated object: moving (translation or rotation)
  • Variation in light: above the threshold of visual perception
  • Visual effect: impression that the object is moving at a different rate to its actual translation or rotation speed
Phantom Array Effect (Ghosting)

- Light source: stationary but varies in intensity or colour
- Observer’s eyes: moving (e.g., large eye movement known as saccades)
- Illuminated object: stationary
  - Variation in light: above the threshold of visual perception
  - Visual effect: gives the impression of a ghosting trail of the object in a person’s vision.
Human Health Effects

• Non-visual effects have been reported as physiological and psychological manifestations including:
  - Migraine
  - Eyestrain
  - Seizures
  - Reduction in task performance
  - Anxiety
  - Autistic behaviour
  - Vertigo
  - Reduction in task performance

• Research activities on visual and non-visual effects of TLAs have endeavoured to establish the:
  - light modulation frequencies and
  - associated thresholds of activation
## Human Health Effects

<table>
<thead>
<tr>
<th>Biological Effect</th>
<th>Frequency range reported</th>
<th>Other conditions reported</th>
<th>Suggested low risk level requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible flicker</td>
<td>0.5 – 35 Hz (8.8 Hz peak sensitivity)</td>
<td>Low threshold for % modulation</td>
<td>Short-term flicker metric, P&lt;sub&gt;st&lt;/sub&gt; LM &lt; 1 (IEC 61000-4-15)</td>
</tr>
<tr>
<td>Photosensitive seizures</td>
<td>3 – 65 Hz (15-25 Hz peak sensitivity)</td>
<td>Visual field ≥ 0.006 sr&lt;br&gt; Luminance change ≥ 20 cd.m&lt;sup&gt;-2&lt;/sup&gt;</td>
<td>≤ 5% Light modulation (frequency independent) or&lt;br&gt; ≤ 20 cd.m&lt;sup&gt;-2&lt;/sup&gt; variation for 3 – 65 Hz</td>
</tr>
<tr>
<td>Stroboscopic effect (moving object)</td>
<td>50 – 2000 Hz</td>
<td>High % modulation&lt;br&gt; Low duty cycles for PWM</td>
<td>Stroboscopic effect Visibility Measure, SVM ≤ 1.6 (NEMA 77)</td>
</tr>
<tr>
<td>Phantom array (eye movement: Saccades)</td>
<td>50 – 3000 Hz</td>
<td>High % modulation&lt;br&gt; Longer saccades</td>
<td>More research required</td>
</tr>
</tbody>
</table>

## Human Health Effects

<table>
<thead>
<tr>
<th>Biological Effect</th>
<th>Frequency range reported</th>
<th>Other conditions reported</th>
<th>Suggested low risk level requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Migraine</td>
<td>• Unknown (But flicker confirmed as trigger)</td>
<td>• None</td>
<td>• More research required</td>
</tr>
<tr>
<td>Autistic behaviour</td>
<td>• Unknown (But indication of flicker as trigger)</td>
<td>• None</td>
<td>• More research required</td>
</tr>
</tbody>
</table>
| Task performance and eyestrain | • < 1250 Hz | • % modulation  
  • Duty cycle for Pulse Width Modulated light output | • ≤ 1% Light modulation (frequency independent) or  
  • Frequency ≥ 1250 Hz |

Mapping the Effects with Frequency Regions

<table>
<thead>
<tr>
<th>Modulation frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>---------------------------</td>
</tr>
<tr>
<td>Biological effects</td>
</tr>
<tr>
<td>--------------</td>
</tr>
<tr>
<td>visible flicker</td>
</tr>
</tbody>
</table>

- Visible flicker
- Photosensitive seizures
- Stroboscopic effect (moving object)
- Phantom array (saccade eye movement)
- Task performance and eyestrain
- Flicker vertigo
- Migraine
- Autistic behaviour
- Panic attack/anxiety
CIE Recommendations

**CIE TN 006: 2016. CIE Technical Note: Visual aspects of time-modulated lighting systems – Definitions and measurement methods.**

**Scope:**
- Visibility of temporal light artefacts

**Out of scope:**
- Application specific acceptability thresholds
- Non-visual effects
- Chromatic flicker

- **Recommends** Short Term Flicker metric, $P_{st}^{LM}$ (from IEC)
- Defines and **recommends** Stroboscopic Visibility Measure (SVM)
- Defines Phantom Array effects

**NOTE:** $P_{st}^{LM}$ and SVM are normalised parameters such that a value of 1.0 is when a person with normal vision will perceive the effect 50% of the time.
% Modulation metric

Simple waveforms

\[
\text{Amplitude} = E_{\text{Max}} - E_{\text{Min}}
\]

Complex waveforms

\[
\text{Modulation} = \frac{\text{Amplitude}}{\text{DC component}} = \frac{(E_{\text{Max}} - E_{\text{Min}})}{(E_{\text{Max}} + E_{\text{Min}})}
\]
Determining Frequency Elements of Complex Waveforms
Possible causes for temporal light modulation

- Light source technology and its driver topology (poor product design)

- Dimming technology of externally applied dimmers or internal light level regulators (poor compatibility)

- Mains voltage fluctuations intentionally applied for mains-signalling purposes (poor immunity)

- Mains voltage fluctuations caused by electrical apparatus connected to the mains (conducted electromagnetic disturbances) (poor immunity)
1. Overview of the Problem
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IEC TR 61547-1 Ed 2 2017: Short term Flicker, $P_{st}^{LM}$

**Equipment for general lighting purposes – EMC immunity requirements – Part 1: An objective 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:

- testing the intrinsic performance of all lighting equipment without voltage fluctuations;
- testing the immunity performance of lighting equipment against (unintentional) voltage fluctuation disturbance on the AC power port;
- testing the immunity performance of lighting equipment against intentional voltage fluctuation on the AC power port arising for example from ripple control systems.

- Describes an objective light flickermeter, including test conditions
- $P_{st}^{LM}$ calculation is a weighted percentile formula based on voltage variations creating perceptible flicker from a 60W incandescent lamp

![Diagram](image-url)
**Equipment for general lighting purposes** –  
**Objective test method for stroboscopic effects of lighting equipment**

**Scope**

The type of equipment under test (EUT) may depend on the purpose of the test. For instance, the following different application tests may be considered (see Figure 2):

- Testing the intrinsic performance of lighting equipment such as luminaires, controlgear or integrated lamps;
- Testing the performance of lighting equipment under dimming conditions.

*Figure 1 – Schematic of the stroboscopic effect measurement method*

*Source: IEC TR 63158: 2018*
Guidance on Limits

- IEC TR 61547-1 does not provide guidance on PstLM limits
- IEC TR 63158-1 does not provide guidance on SVM limits
- NEMA 77:2017 guidance is SVM ≤ 1.6 (page 30, Table 6 in Section 7: Recommendations):

<table>
<thead>
<tr>
<th>Application area</th>
<th>$P_{st}$ limit</th>
<th>SVM limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor</td>
<td>≤ 1.0</td>
<td>None</td>
</tr>
<tr>
<td>Indoor</td>
<td>≤ 1.0</td>
<td>≤ 1.6</td>
</tr>
</tbody>
</table>

- This level relates to the SVM limit on linear fluorescent lamps on magnetic ballasts ($SVM \approx 1.4 - 1.6 @ 100 \text{ Hz}$).
- This would mean the majority of the population would experience stroboscopic effects.

Source: NEMA 77:2017
Another important point is the probability levels assigned to thresholds differ in terms of the proportion of the population affected. The threshold limit levels are defined as:

- 50\textsuperscript{th} percentile of the population, or
- Low risk level (possibly 90\textsuperscript{th} – 95\textsuperscript{th} percentile of the population)
- No observable effect level (possibly 99\textsuperscript{th} – 100\textsuperscript{th} percentile of the population)

- SVM and $P_{st}^{LM}$ limits of 1 are defined for a person with normal vision observing the phenomenon 50\% of the time.
## Mapping All Elements with Frequency Regions

<table>
<thead>
<tr>
<th>LED modules &amp; Driver circuits – typical modulation frequency ranges</th>
<th>Biological effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC ccts</td>
<td>Flicker vertigo</td>
</tr>
<tr>
<td>LEDs with phase cut dimmers</td>
<td>Panic attack/anxiety</td>
</tr>
<tr>
<td>Failure of LED string or rect cct</td>
<td></td>
</tr>
<tr>
<td>Electrical imbalance in LED strings</td>
<td></td>
</tr>
<tr>
<td>very low quality driver design &amp; components</td>
<td></td>
</tr>
<tr>
<td>Pulse Width Modulated ccts</td>
<td></td>
</tr>
<tr>
<td>Full wave rectification cct</td>
<td></td>
</tr>
<tr>
<td>Parallel ½ wave LED string ccts</td>
<td></td>
</tr>
<tr>
<td>Switch Mode Power Supplies</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standards and other bodies (Proposed metrics)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC: Flicker Meter - $P_{st}$ limit</td>
<td>IEEE: Freq based % modulation limits</td>
</tr>
<tr>
<td>CIE recommends: $P_{st}$ limit</td>
<td>CIE: Freq based modulation limits - Stroboscopic Visibility Measure (SVM) &amp; Phantom Array Measure</td>
</tr>
<tr>
<td>IEEE: Freq based % modulation limits</td>
<td>CEC: time based % modulation limits with low pass filters</td>
</tr>
<tr>
<td>LRC Assist: freq based mod limit</td>
<td></td>
</tr>
</tbody>
</table>

**Graphical Elements:**
- DC ccts
- Modulation frequency (Hz)
- Biological effects include:
  - Visible flicker
  - Photosensitive seizures
  - Stroboscopic effect (moving object)
  - Phantom array (saccade eye movement)
  - Task performance and eyestrain
  - Flicker vertigo
  - Panic attack/anxiety
- LED modules & Driver circuits – typical modulation frequency ranges
- Standards and other bodies (Proposed metrics)
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Test results on lamps

Light Waveform

Spectral content - flicker region

Spectral content - stroboscopic region
Test results on lamps

Light Waveform

- DF = 100 Hz
- MD = 25.39%
- Fl = 7.07%
- Pst = 0.7124
- SVM = 0.8530

Spectral content - flicker region

- Light modulation (rel)
- Frequency (Hz)
- Spectral components
- Pst Sensitivity Curve

Spectral content - stroboscopic region

- Light modulation (rel)
- Frequency (Hz)
- Spectral components
- SVM Sensitivity Curve
Test results on lamps

Light Waveform

- DF = 100 Hz
- MD = 102.61%
- FI = 47.78%
- Pst = 0.2001
- SVM = 5.0730

Spectral content - flicker region

Spectral content - stroboscopic region
Test results on lamps

Light Waveform

DF = 100 Hz
MD = 100.46%
EI = 27.65%
Pst = 21.0454
SVM = 3.0462

Spectral content - flicker region

Spectral content - stroboscopic region
European Lamps Tested by CLASP

80% models tested already compliant with requirements
European Lamps Tested by CLASP (...zoom in)

Should the PstLM value be made more ambitious?
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Recommended draft MEPS

- Draft requirements contained in draft MEPS document

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<tr>
<th>Metric</th>
<th>Mandatory Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harmonics</td>
<td>Compliance with IEC 61000-3-2</td>
</tr>
<tr>
<td>Short term flicker indicator (P_{st,LM})</td>
<td>(\leq 1.0^1) at full load and a sinusoidal input voltage.</td>
</tr>
<tr>
<td>(for non-CFL)</td>
<td>Note: compliance with IEC 61547-1</td>
</tr>
<tr>
<td>Stroboscopic effect visibility measure (SVM)</td>
<td>(\leq 0.4) at full load and a sinusoidal input voltage.</td>
</tr>
<tr>
<td></td>
<td>Note: compliance with IEC TR 63158</td>
</tr>
<tr>
<td>Photobiological risk group</td>
<td>For the blue light hazard: RG0 or RG1 are allowed.</td>
</tr>
</tbody>
</table>
Thank you, any questions?

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