

1453™

IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems

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IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems

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of the
IEEE Power Engineering Society

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Abstract: Voltage fluctuations on electric power systems sometimes give rise to noticeable illumination changes from lighting equipment. This phenomenon is often referred to as flicker, lamp flicker, and sometimes voltage flicker. This recommended practice provides specifications for measurement of this phenomenon and recommends acceptable levels for 120 V, 60 Hz and 230 V, 50 Hz AC electric power systems. It does not make any flicker emission specifications for certification of individual products manufactured for use on these systems.

Keywords: flicker, illumination, lamp flicker, voltage flicker, voltage fluctuations

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Introduction

This introduction is not part of IEEE Std 1453-2004, IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems.

Voltage fluctuations on electric power systems sometimes give rise to noticeable illumination changes from lighting equipment. The frequency of these voltage fluctuations is much less than the 50 Hz or 60 Hz supply frequency; however, they may occur with enough frequency and magnitude to cause irritation for people observing the illumination changes. This phenomenon is often referred to as flicker, lamp flicker, and sometimes voltage flicker. Often times, the terms have been used interchangeably. For many years, IEEE Std 141™-1993 and IEEE Std 519™-1992 have contained charts showing allowable voltage fluctuations. These charts in IEEE Std 141-1993 and IEEE Std 519-1992 show allowable voltage change magnitude on the vertical axis and frequency of occurrence on the horizontal axis. Although it is unclear, they appear to be based on 60 Watt, 120 Volt incandescent lamps subjected to rectangular voltage fluctuations. The advent of high-power electronic utilization equipment and mitigation equipment has given rise to some very complex voltage fluctuations that are not easily handled by IEEE Std 141-1993 and IEEE Std 519-1992. For this reason, the IEEE has worked in close cooperation with the International Union for Electroheat (UIE) and the International Electrotechnical Commission (IEC) to enhance existing standards to include a broader part of the world community.

This recommended practice is based on specifications that were prepared by the Disturbances Working Group of the UIE and published in 1992 with the international agreement for the 120 V power system published in the UIE congress in 1996. Consequently, the flickermeter specifications in this standard relate only to measurements of 230 V, 50 Hz and 120 V, 60 Hz inputs; specifications for other voltages and other frequencies are under consideration.

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IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems

1. Overview

1.1 Scope

Voltage fluctuations on electric power systems sometimes give rise to noticeable illumination changes from lighting equipment. This phenomenon is often referred to as flicker, lamp flicker, and sometimes voltage flicker. This recommended practice provides specifications for measurement of this phenomenon and recommends acceptable levels for 120 V, 60 Hz and 230 V, 50 Hz AC electric power systems. It does not make any flicker emission specifications for certification of individual products manufactured for use on these systems.

1.2 Purpose

The purpose of this recommended practice is to provide basic information for the design of an analog or digital flicker measuring apparatus. This recommended practice also sets tolerable limit values for flicker severity.

Specifically, this recommended practice adopts the IEC 61000-4-15 for a functional design specification for flicker measuring apparatus intended to indicate the correct flicker perception level for all practical voltage fluctuation waveforms. Information is presented to enable such an instrument to be constructed. A method is given for the evaluation of flicker severity on the basis of the output of flicker meters complying with this recommended practice.

This recommended practice will supersede 3.9.2 and Figure 3-8 in IEEE Std 141™-1993 [B5]¹ and 10.5.1 and Figure 10.3 in IEEE Std 519™-1992 [B6].

¹The numbers in brackets correspond to those of the bibliography in Annex C.

2. References

This recommended practice shall be used in conjunction with the following publications. If these publications are superseded by an approved revision, the revision shall apply.

IEC 61000-4-15, Electromagnetic compatibility (EMC)—Part 4: Testing and measurement techniques—Section 15: Flickermeter—Functional and design specifications.

IEC 61000-3-3, 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 61000-3-5, Electromagnetic compatibility (EMC) - Part 3: Limits—Section 5: Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 16 A.

IEC 61000-3-7, Electromagnetic compatibility (EMC)—Part 3: Limits—Section 7: Assessment of emission limits for fluctuating loads in MV and HV power systems—Basic EMC publication.

3. Definitions

For the purposes of this recommended practice, the following terms and definitions apply. Most of these definitions are in IEC 61000-4-15. *The Authoritative Dictionary of IEEE Standards Terms* [B4] should be referenced for terms not defined in this clause. Note specifically that definitions 3.2 through 3.5 are adopted within this document for consistency with the IEC 61000 series upon which this document is based; thus they may conflict with ANSI C84.1 [B1] and *The Authoritative Dictionary* [B4] accepted definitions.

3.1 compatibility level: The specified disturbance level used as a reference level in a specified environment for coordination in the setting of emission and immunity limits. This is normally taken as the level of Pst or Plt above which customer complaints are likely to occur. These levels are not used for assessing individual load compliance

3.2 extra high voltage (EHV): Voltage levels that are greater than 230 kV.

3.3 high voltage (HV): Voltage levels that are greater than 35 kV, but less than or equal to 230 kV.

3.4 low voltage (LV): Voltage levels that are less than or equal to 1 kV.

3.5 medium voltage (MV): Voltage levels that are greater than 1 kV, but less than or equal to 35 kV.

3.6 planning level: The level of a particular disturbance, in a particular environment, adopted as a reference value for the limits to be set for the emissions from large loads and installations, in order to coordinate those limits with all the limits adopted for equipment intended to be connected to the power supply system. In planning studies, this is the level of Pst or Plt used to assess the impact of adding fluctuating loads to the electric power system.

3.7 Plt: A measure of long-term perception of flicker obtained for a two-hour period. This value is made up of 12 consecutive Pst values per the following formula:

$$\text{Plt} = \sqrt[3]{\frac{1}{12} \sum_{j=1}^{12} \text{Pst}_j^3}$$

3.8 Point of Common Coupling (PCC): The point on the MV, HV, or EHV bus on the electric power system electrically closest to a particular fluctuating load, at which point other loads are or could be connected.

3.9 Pst: A measure of short-term perception of flicker obtained for a ten-minute interval. This value is the standard output of the IEC flickermeter.

4. Requirements for flicker measurement and acceptable flicker levels

4.1 Adoption of IEC 61000-4-15

IEC 61000-4-15 is adopted and approved for use as IEEE Std 1453. IEC 61000-4-15 is incorporated directly into this document as normative Annex D.

4.2 Additional requirements

4.2.1 Statistical compliance

IEC 61000-3-7 indicates that probability levels are generally used for determining compatibility levels for compliance. Thus, for 95% probability and given the 1008 Pst intervals in a week, a connected load could exceed the recommended Pst value for 50 ten-minute intervals and still remain within compliance. It is preferred, however, that the 99% probability level be used; thus only 10 Pst intervals in a week could be exceeded and compliance maintained. These probability levels are based on cumulative distribution calculations. By setting flicker limits such that the planning levels are exceeded only a small percentage of the time, customer complaints and equipment malfunctions will be minimized. As a general guideline, Pst and Plt should not exceed the planning levels more than 1% of the time (99% probability level), with a minimum assessment period of one week.

4.2.2 Planning levels for flicker

For planning purposes, the flicker levels listed in Table 1 are recommended. These levels are to be used when evaluating the impact of fluctuating loads on the power system.

Table 1—Planning levels for Pst and Plt in MV, HV, and EHV power systems

	Planning levels	
	MV	HV–EHV
Pst	0.9	0.8
Plt	0.7	0.6

4.2.3 Compatibility levels for flicker

For LV and MV power systems, the flicker levels listed in Table 2 are recommended and are based on 95% probability levels. These are generally considered to be levels below which there will be no complaints due to voltage fluctuation.

Table 2—Compatibility levels for Pst and Plt in LV and MV power systems

	Compatibility Levels
Pst	1.0
Plt	0.8

4.2.4 Acceptance of flicker causing loads to electric supply systems

Users should consider IEC 61000-3-3 for analyzing new fluctuating emissions to electric power systems. IEC 61000-3-3 presents the usage of shape factors to determine anticipated flicker levels for proposed loads on the power system. Recently, there has been some effort to develop software to allow the engineer to graphically analyze flicker levels due to fluctuating loads. These programs provide similar results to those obtained by utilizing shape factors, but the details of the calculation are hidden to the user. IEC 61000-3-7 proposes a three-stage method of evaluating acceptability of fluctuating loads and provides go/no-go limits such that design calculations can be minimized.

4.2.5 Maximum allowable voltage drop for infrequent events

The flickermeter is better suited for events that occur once per hour or more often. The limitations from IEEE Std 141-1993 [B5] and IEEE Std 519-1992 [B6] are still useful for infrequent events, such as a motor starting infrequently (1 start per day), or even as frequent as some residential air conditioning equipment. Therefore the allowable limits from IEEE Std 141-1993 [B5] have been provided in informative Annex A for guidance.

Annex A

(informative)

Brief history of voltage flicker limits in the United States

Figure A.1 is the flicker curve that North American utilities have used for many years, commonly referred to as the GE curve. The development method behind these curves is given in Brieger [B2]. Additional background information and a survey of North American utility flicker criteria are given in Walker [B15] and Seebald, et al [B10]. This recommended practice builds upon these previous methods. The advent of solid-state compensators and loads may produce modulation of the voltage magnitude that is more complex than what is envisioned by the original flicker curves. This recommended practice introduces an instrument based on IEC 61000-4-15 that more accurately accounts for these complexities.

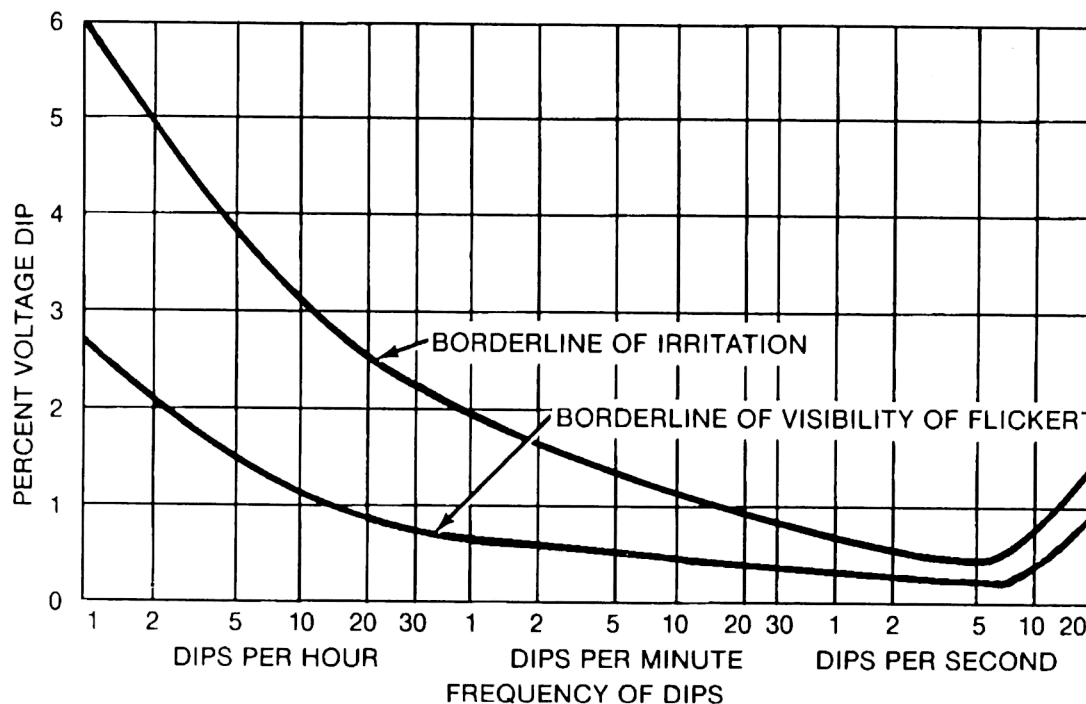


Figure A.1—Flicker tolerance curve from IEEE Std 141-1993/IEEE Std 519-1992

The 230 V and the 120 V IEC flickermeters are physiologically equivalent. The $P_{st} = 1$ pu curves for 120 V and 230 V lamps indicate the same degree of annoyance (borderline of irritation). They are both based on the use of a 60 W incandescent lamp. Studies have been performed with other wattage and type lamps. The related relative voltage changes are given in the following Table A.1 for rectangular modulation.

Table A.1—Pst = 1 test points for rectangular voltage fluctuations, from [B3]

Col.1 Changes per minute	Col.2 Fluctuation Frequency Hz	Col.3 Pst=1 Relative voltage changes for unit flicker severity for 230 V lamps $\Delta V/V$ (%)	Col.4 Pst=1 Relative voltage changes for unit flicker severity for 120 V lamps $\Delta V/V$ (%)
0.1	0.000833	7.400	8.202
0.2	0.001667	4.580	5.232
0.4	0.003333	3.540	4.062
0.6	0.00500	3.200	3.645
1	0.00833	2.724	3.166
2	0.01667	2.211	2.568
3	0.02500	1.95	2.250
5	0.04167	1.64	1.899
7	0.05833	1.459	1.695
10	0.0833	1.29	1.499
22	0.1833	1.02	1.186
39	0.3250	0.906	1.044
38	0.4000	0.87	1.000
68	0.5667	0.81	0.939
110	0.9167	0.725	0.841
176	1.4667	0.64	0.739
273	2.2750	0.56	0.650
375	3.1250	0.50	0.594
480	4.0000	0.48	0.559
585	4.8750	0.42	0.501
682	5.6833	0.37	0.445
796	6.6333	0.32	0.393
1020	8.5000	0.28	0.350
1055	8.7917	0.28	0.351
1200	10.000	0.29	0.371
1390	11.583	0.34	0.438
1620	13.500	0.402	0.547
2400	20.000	0.77	1.051
2875	23.9583	1.04	1.49

Table A.1 supersedes flicker charts in IEEE Std 519-1992 [B6] and IEEE Std 141-1993 [B5]. For comparison, the following Figure A.2 compares this recommended practice with the previous IEEE flicker standards. Work done by the UIE was subsequently adopted by the IEC. The UIE continues their efforts in this area as evidenced by their reference on the following graph.

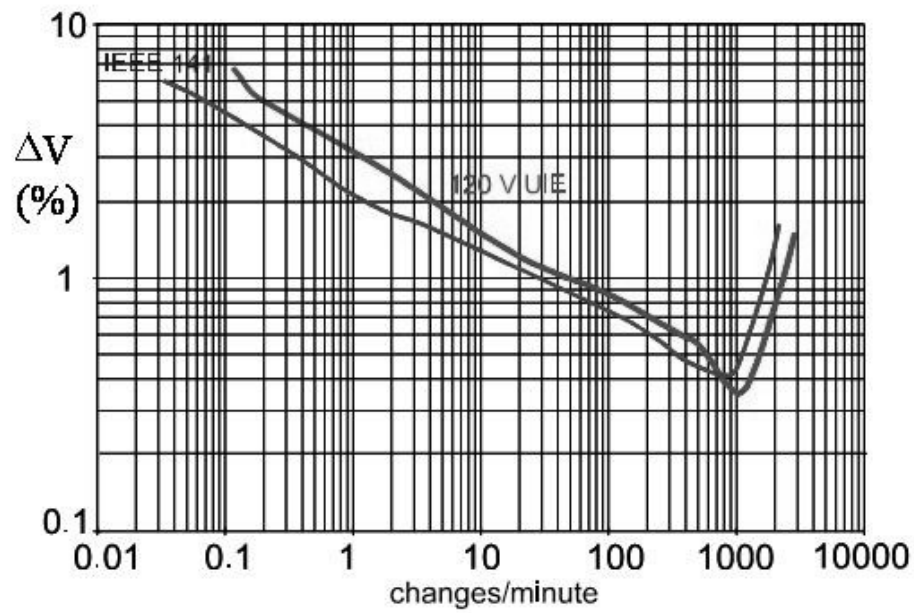


Figure A.2—Comparison of IEC 61000-4-15 and IEEE Std 141-1993 for irritation

Annex B

(informative)

Application of Pst

There are many issues relating to flicker evaluation and measurement implementation that require additional research. Some of these are the effect of interharmonics on flicker, the determination of flicker transfer coefficients from HV to LV electric power systems, aspects of a completely digital implementation, and others. Issues such as these will be addressed in future revisions of this recommended practice.

A detailed description of the flickermeter implementation and the evaluation of the connection of fluctuating loads to the electric power system can be found in numerous references ([B7], [B11], [B12], [B13], [B14]).

A recent paper included a survey of Pst limits used by a variety of different countries (Koch and Sakulin [B8]). NRS-048-2:1996 [B9] is a specific national standard for one of these countries.

The IEC has published a series of standards (IEC 61000-3-3, IEC 61000-3-5, IEC 61000-3-7) based on the Pst evaluation of flicker. IEC 61000-3-3 describes the allowable voltage fluctuations generated by equipment with a current rating less than 16 amperes. IEC 61000-3-5 describes the allowable voltage fluctuations generated by equipment with a current rating greater than 16 amperes. IEC 61000-3-7 describes the allowable voltage fluctuations in medium voltage, high voltage, and extra high voltage electric power systems and the allowable emissions of voltage fluctuations generated by each fluctuating load connected to the electric power system.

The application of shape factor allows the effect of loads with voltage fluctuations other than rectangular to be evaluated in terms of Pst values and is described in IEC 61000-3-3, IEC 61000-3-7, and IEEE PES 01TP151 [B3].

Annex C

(informative)

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[B4] IEEE 100, *The Authoritative Dictionary of IEEE Standard Terms*, Seventh Edition, New York, The Institute of Electrical and Electronics Engineers, Inc.²

[B5] IEEE Std 141-1993, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants—Red Book.

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Annex D

(normative)

IEC 61000-4-15

**NORME
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61000-4-15

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