ELECTRIC POWER RESEARCH INSTITUTE

PQTN BRIEF

Power Quality Testing Network

Published by the Electric Power Research Institute Brief No. 24 2007

Perception Thresholds of Flicker in Modern Lighting

Background

Excluding blinking clocks and computer lockups, flickering lights may be the most perceivable consequence of voltage disturbances to residential and commercial customers. Yet today's North American flicker standards can be traced to a flicker curve composed in 1921 by Willard C. Brown, an engineer from the National Lamp Works of General Electric, and published in 1925. The curve, shown in Figure 1, conveys the relationship between the magnitude and frequency of voltage fluctuations and human perception of the flicker in an incandescent lamp resulting from these voltage fluctuations. Subsequent flicker research has not kept up with the remarkable advances in lighting technologies. Although the "GE Flicker Curve" has served the utility industry well and is still valid for standard incandescent lighting, the introduction and widespread use of high-tech magnetic and electronic ballasts raise questions about its applicability to modern lighting. This Brief reports the results of recent research to characterize the response of human observers to lamp flicker in modern lighting.

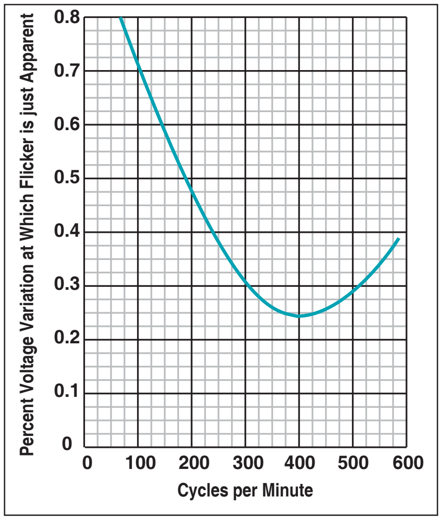


Figure 1. First North American "Flicker Curve" Composed by Willard C. Brown in 1921

Objective

The objective of the tests performed at the University of New Brunswick Department of Psychology was to determine whether perception thresholds of humans to flicker in modern magnetic, electronic, and halogen lighting is significantly different from their reaction to flicker in a standard 60-watt incandescent lamp.

Test Setup

Testing was conducted in a cubicle with smooth, white interior walls, light tan floor, and a ceiling covered with white, perforated acoustic tile. During the tests, human subjects sat at a desk and read from a book placed directly in front of them on a desk covered with white posterboard. The only source of light in the room during testing was the ballast/lamp under investigation. During each trial, the light level of the lamp was adjusted to 593 lux, measured just above the surface of the book. Two photometers—one directed at the book and the other at the lamp—provided light intensity data to a computer. An arbitrary-wave generator and power amplifier supplied 60-Hz, 120-V power to the ballast/lamp under test. To create flicker, the ballast input voltage was modulated with a 5-, 10-, and 15-Hz square wave that slowly descended in amplitude from 2.5% to 0% of the input voltage in 25 steps. The human subjects were instructed to push a button connected to the computer when they observed that the flicker had stopped. Figure 2 shows the test setup.

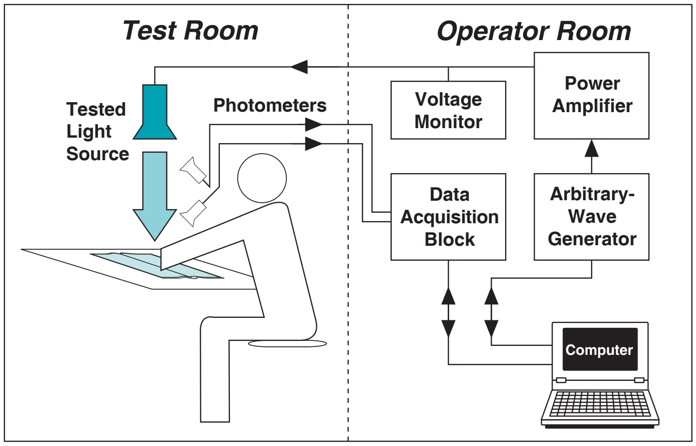


Figure 2. Test Setup

Test Results

Seven lamps or ballast/lamp combinations were selected for testing from 55 different models based upon their gain factors (for a thorough discussion of gain factor, see PQTN Brief No. 23). Compared to a standard 60-watt incandescent bulb, some had higher gain factors while others had lower gain factors over the range of 5- to 15-Hz voltage modulation. Of the seven lamps or ballast/lamps selected, two were four-foot fluorescent fixtures with electronic ballasts (64 and 80 watts), two compact fluorescent lamps (CFLs) with magnetic ballasts (13 and 15 watts), one a 15-watt CFL with an electronic ballast, one a 45-watt halogen lamp, and one a standard 60-watt incandescent bulb.

The light from each lamp was observed by six subjects while the lamp was subjected to voltage fluctuations. When subjects pushed the button to indicate that they no longer perceived the flicker, the computer recorded the percent of modulation (from 0% to 2.5%) of the control voltage. The six data points were averaged for each lamp or ballast/lamp combination. Figure 3 shows the results. The taller columns indicate lamps or ballast/lamp combinations with greater tolerance to voltage fluctuations (less perceptible flicker for the same amount of voltage fluctuation). For each lamp, the perception thresholds of the six subjects varied widely. Figure 4 shows the recorded maxima, minima, and variance (square of the standard deviation) for flicker perception of all lamps at 10 Hz.

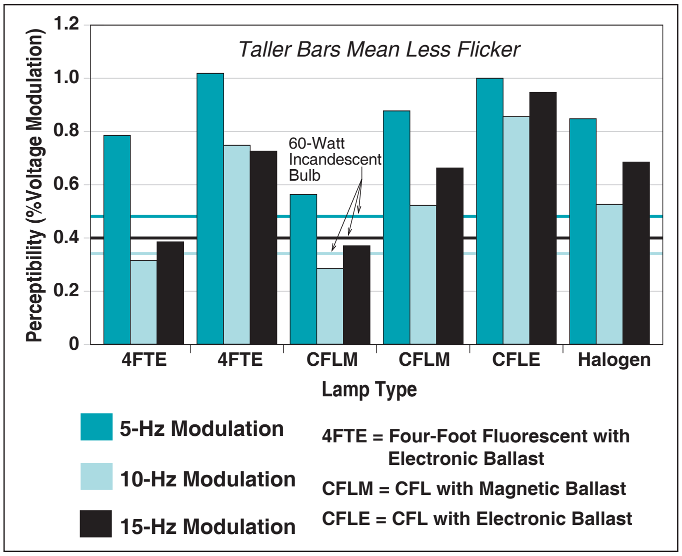


Figure 3. Flicker Perception Thresholds for Descending Modulation at Three Different Frequencies

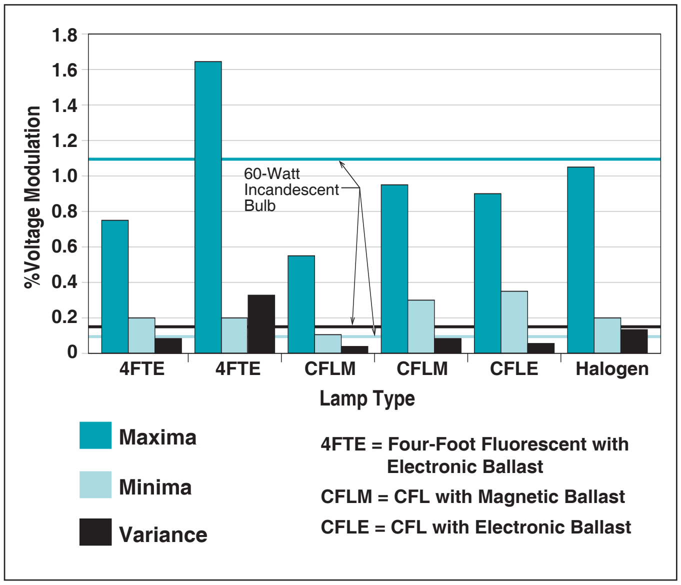


Figure 4. Maxima, Minima, and Variance of Human Flicker Perception Thresholds at 10 Hz

DISCUSSION

In these tests, a descending level of modulation was chosen over an ascending level because it produces the more common experience of observing flicker and waiting for it to go away. Although these tests were not intended as a comprehensive investigation, the results demonstrate that the type of ballast used to power a fluorescent lamp affects the amount of observable flicker. Of the three electronic ballast/lamp combinations tested, only one produced more noticeable flicker than a 60-W incandescent lamp at 10 and 15 Hz, but none produced more flicker at 5 Hz (based on an average of six subjects). This result was expected because the thermal inertia of the filament in the incandescent lamp slows its response to voltage fluctuations at higher frequencies. One of the two magnetically ballasted lamps produced more noticeable flicker at 10 and 15 Hz than the incandescent lamp during human perception testing. However, as shown in Figure 4, there was a wide range of perceptions with several lamp types.

SIGNIFICANCE

Concern over light flicker has been a basic criterion for electrical power system design since the invention of alternating-current generators and electric lights. Now, over 100 years after power-systems engineers began making design decisions to meet the demands of electric lighting, new lighting designs have lowered the bar, making it even more difficult for utilities to maintain acceptable levels of voltage fluctuation. Perhaps at this point in lighting history (see Tutorial), we need to look at modifying the design of lighting rather than rebuilding the electric power system. In any event, efforts are needed to coordinate existing voltage-fluctuation standards with lighting design criteria and to take advantage of the practically flicker-free performance potential of modern lighting.

ACKNOWLEDGMENTS

This work was conducted by the New Brunswick Research and Productivity Council at the University of New Brunswick Department of Psychology and was sponsored by EPRI, the Canadian Electrical Association, and the sponsors of the EPRI Host Utility Electronic Ballast and Compact Fluorescent Lamp Characterization Project. Special thanks to Ed Owen of GE for his help in developing the tutorial.

TUTORIAL: The Influence of Flicker on Power System Designs

1891 The pioneers of the North America power industry select 60 hertz as the standard frequency for the electric power system to prevent visible flickering in open-type arc lamps. Europeans select 50 hertz based on the flicker response of enclosed-type arc lamps.

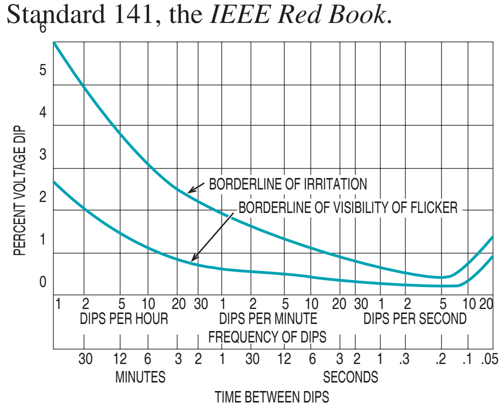
1921 A General Electric engineer researches human response to lower-frequency flicker (0 to 10 hertz) found in 115-volt, tungsten-filament lamps and caused by low-speed, motor-driven reciprocating compressors.

1925 General Electric publishes the "GE Flicker Curve" rendered from the 1921 research. The curve eventually becomes a standard for voltage design in North American electric utilities.

1937 Utilities Coordinated Research completes a comprehensive study on human perception of flicker, which validates the GE flicker Curve for cyclic flicker and recommends a voltage limit for non-cyclic flicker.

1950s Electric utilities become concerned about the "stroboscopic effects" of the new fluorescent lamps, but research confirms that the standard 120-volt incandescent lamp remains the type of lighting most prone to flicker, especially at low pulsation rates.

1964 A modified GE Flicker Curve, for cyclic and non-cyclic pulsations, is published in IEEE Standard 141, the *IEEE Red Book*.



1985 An IEEE survey reveals that 69% of the responding electric utilities used the updated GE Flicker Curve as their voltage standard.

1994 A flicker study conducted by EPRI and the Canadian Electrical Association finds that some new electronic and compact fluorescent lamps are more prone to flicker and some less prone than the standard incandescent. The study also reveals that some lamp dimmers tend to amplify light flicker.

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