Brief 23: Light Flicker in Compact Fluorescent Lamps Caused by Voltage Fluctuations

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Electronic Ballast
Load Switching
Magnetic Ballast
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Background

Although today's electric power utilities generate the cleanest electricity in history, electric power is susceptible to disturbances from nature and from the utility customers themselves. Voltage fluctuations, a common power line condition, can be caused by load-switching events (motor starting in fans, pumps, and compressors), intermittent loads (presses or crushers, welders, and arc furnaces), and events originating outside end-user facilities (power line resonances and capacitor switching). Because even slight voltage fluctuations can cause lights to flicker, utilities have pursued a remedy for flicker since the late 1930s. At that time, researchers developed the first flicker curves (line charts), which define the limits of voltage fluctuations that cause perceptible flicker in incandescent lamps.

By sponsoring rebate and discount programs for customers who install efficient lighting, the utility industry is encouraging many advances in lighting technologies. Yet utilities still rely on the original flicker curves to define reasonable limits for voltage fluctuations. To determine how the same voltage fluctuations affect the electronic and magnetic ballasts that power today's energy-efficient fluorescent lamps, a research program is being conducted in three stages. The first stage, characterizing the responses of various new lighting systems to voltage fluctuations, has been completed. The second stage, characterizing the responses of human observers to lamp flicker, is still in progress. The third and last stage, using the test data from the first two stages to develop new flicker curves applicable to new lighting technologies, is planned to begin in 1995.

Objective

The objective of the tests performed at the EPRI Power Electronics Applications Center (PEAC) Power Quality Test Facility was to characterize the light output of an incandescent lamp and compact fluorescent lamps during voltage fluctuations.

Test Setup

Two samples each of twenty-six compact fluorescent lamp (CFL) models-19 containing electronic ballasts (9 US and 10 Canadian) and 7 containing magnetic ballasts (5 US and 2 Canadian)-and one 60-W incandescent lamp were tested. All lamps were rated at 120 Vac. To stabilize the lamp characteristics before testing, each lamp was operated for 100 hours. As part of the test chamber, a photometer measured the light output of each lamp.

Data from the photometer was amplified, filtered, and then processed by a computer with a data-acquisition card. Figure 1 shows the test setup.

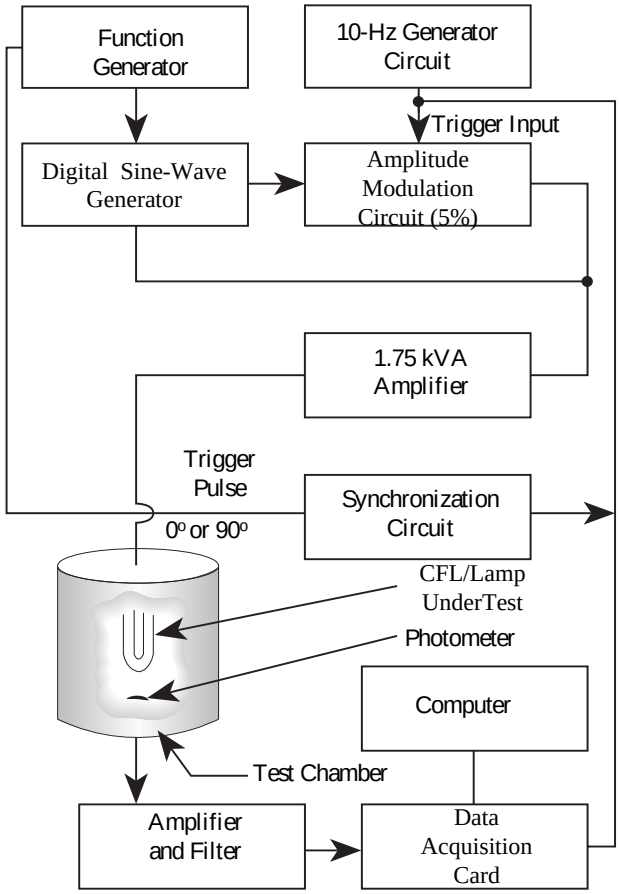


Figure 1: Test Setup

Test Results

Each lamp was connected to the test setup and operated for 10 minutes in the test chamber before any measurements were made. Then, the rated input voltage (120 Vac) was applied while the photometer measured the light output of each lamp to determine a baseline profile of light output. Next, the input voltage to each lamp was modulated at 5% by a 10-Hz square wave, while the photometer measured the light output of each lamp (see Figure 2). (A 10-Hz square wave was used because the results of human perception testing indicate that the most noticeable cyclic flicker is caused by voltage fluctuations with this form and frequency.) The computer analyzed the baseline and modulated-voltage profiles to determine a gain factor (GF), which is the numerical relationship between change in input voltage and change in light output (see Tutorial). Table 1 shows the average gain factors of the two samples of each CFL tested (incandescent lamp = 2.5).

	U.S.A	Electronic									Magnetic				
		1.7	1.5	1.5	1.5	3.3	1.3	1.2	0.8	1.2	2.4	2.2	3.1	2.4	2.3
	Canada	Electronic										Magnetic			
		1.9	2.3	2.3	1.4	1.2	2.6	3.9	2.2	2.9	3.6	3.0	4.3		

Table 1: Gain Factors for the CFLs (Incandescent Lamp = 2.5)

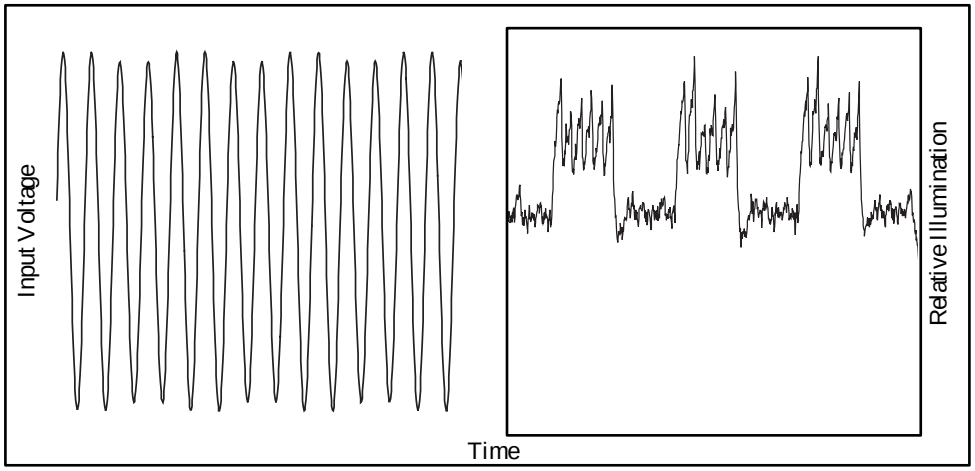


Figure 2: CFL Input Voltage Modulated with 5% 10-Hz Square Wave (left) and Relative Illumination (right)

Discussion

According to the calculated gain factors, a magnetic CFL produces slightly less to significantly more flicker than a typical incandescent lamp during the same amount of voltage fluctuation (GF = 2.2 to 4.3). The responses of the electronic CFLs to 10-Hz voltage fluctuations also varied widely, the gain factor ranging from 0.8 to 3.9. However, whereas the average gain factor of the magnetic CFLs (2.8) was slightly higher than the incandescent lamp (2.5), the average gain factor of the electronic CFLs (2.0) was lower.

Significance

Although modern magnetic and electronic CFL lighting products save millions of kilowatt-hours and thereby eliminate tons of pollutants each year, their responses to voltage fluctuations vary from model to model. Most produce less flicker than the incandescent lamp; yet some produce more. Perhaps the most consequential result of current flicker testing is the indication that the flicker curves in use today provide inadequate voltage-fluctuation criteria for the wide variety of modern lighting. To better understand the relationship between voltage fluctuations and perceptible flicker, standards-writing organizations-such as the American National Standards Institute (ANSI) and the Institute of Electrical and Electronic Engineers (IEEE)-are teaming with EPRI, the Canadian Electrical Association, and the manufacturers of lighting products to conduct flicker research. The standards resulting from such research-and potential

pressure from end users who value a flicker-free environment-are intended to motivate manufacturers to design lighting products with lower gain factors.