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Arbitrary waveform generator for harmonic distortion tests on compact fluorescent lamps

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Abstract

This paper presents an experimental method to perform tests on compact fluorescent lamps operated with distorted voltage waveform conditions. The voltages used for the tests are obtained from an arbitrary waveform generator. It consists of a computer, a multifunction card and the software package. The characteristics of the voltage are entered from the computer that loads the required waveform into the card. The output of the card is driven to a voltage amplifier to supply the lamps. Samples of the voltage across the load and of the circulating current are recorded and transferred to the computer for harmonic analysis. The user supervises the tests through several virtual instruments that have been developed especially for this application. The system facilitates the performance evaluation of various appliances for distorted supply voltages. The cost of the system is very low compared with a conventional system consisting of an arbitrary waveform generator, a digital oscilloscope, a spectrum analyzer or/and a computer for harmonic analysis and a true rms multifunction meter. The experimental results show that the distribution of the harmonics of some lamp types does not alter linearly under distorted supply voltages. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Arbitrary waveform generator; Power system harmonics; Compact fluorescent lamps; Power quality

1. Introduction

As part of energy conservation strategy, many electric power utilities are promoting modern technologies that consume less energy while providing better quality. In this category belongs the compact fluorescent lamp (CFLs). This electrical equipment is of great importance in lighting since it can provide significant energy saving and last longer than incandescent lamps.

CFLs operate at a low power factor consuming less active power, providing comparable luminous output to the incandescent lamps [1]. However, the ballasts of compact fluorescent lamps can be an important source of higher-order harmonic components of current. These lamps induce distorted current waveform, which influence the quality of the supplied power as well as the electrical appliances [2,3].

The current of the CFLs has not a purely sinusoidal waveform and it is characterised by rapid amplitude changes, a fact that among others creates distortion in the voltage waveform. The effect of CFLs on the distribution system has been investigated and found out that a low percentage of CFLs

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may be sufficient to cause voltage distortion in excess of 5% [4]. Some CFLs have total harmonic distortion (THD) of current higher than 100%, but they have low active power compared with other high-THD sources such as personal computers. That is the reason why standards organisations have not set power quality requirements for CFLs [5,6]. ANSI defines a limit of 32% [7] as the maximum current THD of electronic lamps. This standard also specifies the limit of the amplitude of all high-order harmonics to 30% of the fundamental amplitude. The upper limit of all the higher than the 11th order harmonics is defined as 7% of the fundamental. The limit of the current THD of electronic ballasts is 20%, according to IEEE [5] and IEC [6].

The increasing use of electrical devices (computers etc.), which are sources of harmonics causes distortion in the line voltage. Consequently, it is possible for some CFL lighting systems to be installed in locations where the supply voltage is not always pure sinusoidal. In this case, the harmonic components of the line voltage may affect the performance of CFLs. The aim of this project is to develop an experimental apparatus for the investigation of the harmonic distortion and the problems that may be caused to the distribution network by CFLs as well as to the CFL's performance.

2. Experimental apparatus

2.1. General description

The voltages used for the tests are obtained from an arbitrary waveform generator. It consists of a computer, the multifunction card AT-MIO-16E-10 of National Instruments, the software package and a voltage amplifier.

The components of the voltage are entered from the computer, which loads the required waveform into the card. The analogue output of the card is driven to a voltage amplifier, where it is amplified up to 250 V, AC in order to supply the lamps. The lamps are mounted base-up as their regular burning position. The experimental apparatus is sketched in Fig. 1.

The supply voltage and the current waveforms are recorded and transferred into the computer through analogue inputs of the card. Both waveforms are analysed and their harmonic components are computed.

The computer controls the experimental procedure using Lab View software package. The environment of Lab View is very friendly for developing programmes using graphical programming language. It uses terminology, icons and ideas familiar to scientists and engineers and relies on graphical symbols rather than textual language to describe programming actions. It has extensive galleries of functions and subroutines for most programming tasks including data acquisition. Virtual instruments (VIs) imitate actual instruments.

The experimental procedure of this project is split into a series of tasks that can be divided again until the complicated application becomes a series of simple subtasks. The tasks and the subtasks are performed by the user of the computer via several VIs that have been especially developed for the purposes of the project.

2.2. Arbitrary waveform generator

The characteristics of the supply voltage are defined by a VI, which simulates the panel of the physical instrument. It contains an interactive user interface that is the front panel of the arbitrary

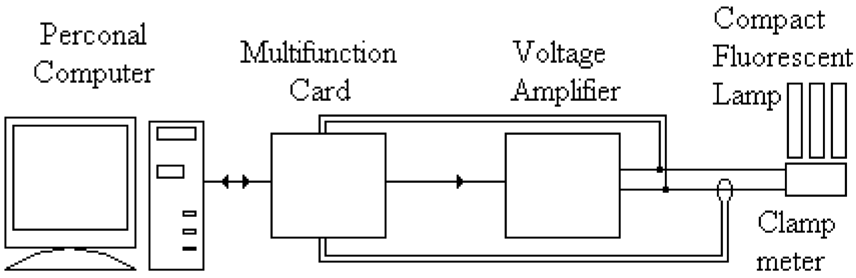

Fig. 1. Experimental apparatus.