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Evaluation of Harmonic Variability in Electrical Power Systems through Statistical Control of Quality and Functional Data Analysis

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Abstract

The presence of harmonics in power systems and their problems and impact on quality of electricity supply is increasing due to the increase in society's use of the nonlinear loads that generate them, especially the electronic kind. Classic techniques such as Statistical Process Control (SPC) and Process Capability Analysis (PCA) that form the Statistical Quality Control, can be used to identify outliers or special causes of variability, and proceed with the implementation of actions allowing corrective disposal, provided that the harmonics are normally distributed. In the event that the distribution is unknown novel tools such as Functional Data Analysis (FDA), have been used successfully in this communication to study these phenomena in situations where the classic quality control cannot.

*Keywords:*harmonics; variability; outlier; statistical process control; functional data analysis

1. Introduction

In recent decades there has been a considerable increase in the use of equipment, both domestic and industrial, that includes electronic power converters, Balcells (2003). The functioning principle of these pieces of equipment consists of “cutting up” the sinusoidal waveform in order to control the power flow that they consume, or in rectifying, through the use of semiconductors, this sinusoidal wave to turn it into direct voltage. The commutation or rectification processes mean that the waveform of the intensity that these pieces of equipment consume is no longer sinusoidal, that is, they are non-linear loads. The circulation of these currents distorted by the impedances of the distribution system mean that, in turn, the voltage of the supply power grid also ceases to be purely sinusoidal,

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causing major negative consequences in industrial processes, Wargner (1993). That is why there is a need to study it, despite its difficulty.

However, the collection of data from electrical power systems is often voluminous and, in most cases, data are stored in large databases without them being studied, either due to the time required for the analysis or because the right tools are not available. This work successfully presents traditional and new tools to solve these contingencies, and thereby improves on some works carried out to date, Santoso et al. (2012).

2. Description and methodology of the case study

For the study carried out in this work, we used two samples relating to the measurements made in the 400V three-phase low-voltage output of the transformer substations for the two buildings of the Centro Universitario de la Defensa, between 04/11/2012 and 13/12/2012. The electrical measurements, whose characteristics appear in Table 1, were made by using the Circutor QNA-PV power quality analyzer and were recorded on the indicated dates at intervals of 10 minutes.

Table 1. Characteristics of the study samples.

	Name	Days	Data/day	n
Félix de Azara Building	Sample A	39	144	5616
Conde de Aranda Building	Sample B	39	144	5616

3. Analysis of variability and outliers in electrical power systems

In classic statistical terminology, an outlier is defined as an observation that by being atypical or erroneous has a very different behaviour compared to the other distribution data of which it is part, giving an approximate idea of the variability of the distribution. In the analysis of harmonics, when the variability and its causes are being analysed, the charts offered by the software of the majority of measuring equipment, as shown in Figure 1 for example, are not the most appropriate ones. Different techniques are proposed for the above purpose in the following sections.

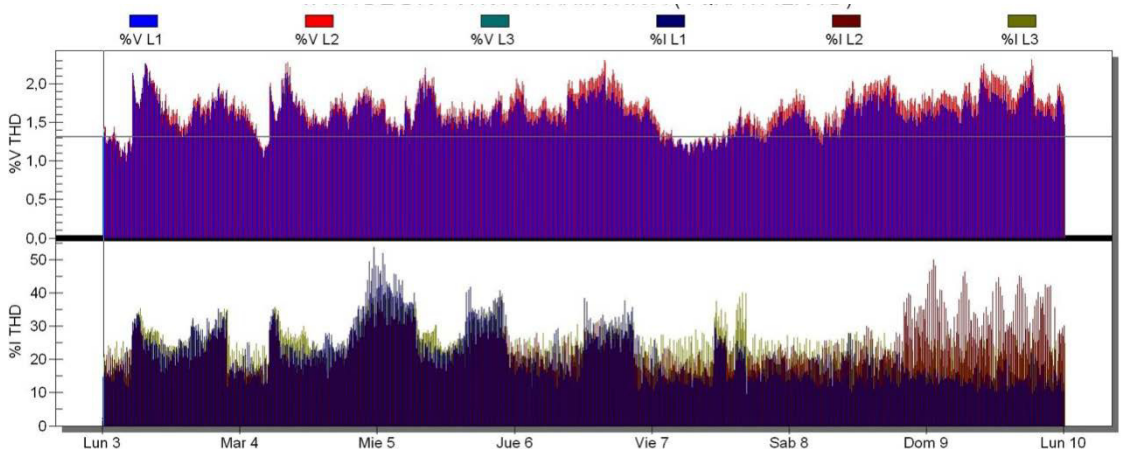

Fig. 1. Typical Chart for the Harmonic Distortion Rate.

3.1. Global Outliers. Analysis of Box Plots

Box plots are charts that simultaneously describe how all of the data being analysed are distributed. They make it possible to globally detect “abnormal” observations or outliers. Specifically, a box plot shows the three Q1, Q2, and Q3 quartiles (first, second or median, and third), the minimum and the maximum of the data in a rectangular box. To