

A CASE OF POWER QUALITY ASSESSMENT USING A DEVELOPED POWER QUALITY MONITOR

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Abstract. This work presents an example of a power quality assessment study in an electrical panel that supplies investigation laboratories, office rooms and an electronics workshop, using a developed Power Quality Monitor. The results of this study are analyzed using international standards as reference in order to determine the quality of the supplied energy. The technical specifications of the developed monitor are also portrayed, together with a summary of its applications.

1 INTRODUCTION

Nowadays, power quality is a key issue for the producers, distributors and consumers. The most common problems, like harmonics, short term voltage variations (sags, swells and interruptions), long term voltage variations (undervoltages, overvoltages and interruptions), transients, unbalance, frequency variations and others, can cause several problems to the consumers which require high levels of power quality for their industrial processes or home use.

Power quality studies are the necessary first step in order to determine what is wrong, so that measures can be taken to solve the problems. Several international standards related to power quality and electrical system monitoring, like IEEE 519, IEC 61000 and EN 50160, help to classify and even offer possible solutions to the problems described above, but specialized equipment is necessary in order to find which problems affect a given facility [1-3].

Because many of the commercially available equipments are either too expensive, or have too many limitations, it was decided to develop a new low-cost power quality monitor that could be an alternative to the equipment in the market.

In order to test the developed Power Quality Monitor, and prove its capabilities, a study was performed at the facilities of the Industrial Electronics Department of University of Minho. This power quality assessment involved monitoring an electrical panel that supplies 4 research laboratories, 10 office rooms and an electronics workshop. Figure 1 shows the developed equipment at the electrical panel. The paper presents results from a first session that lasted 7 days, and from a second 3 days session when some interesting events were recorded.

2 DEVELOPED POWER QUALITY MONITOR

The developed low-cost Power Quality Monitor consists of a standard Personal Computer (Pentium III running Windows XP), a data acquisition card (National Instruments MIO-PCI-6024E), and a custom made hardware module [4]. The card can read 8 analogue signals in differential mode, with a 12 bit resolution and a 200 ksamples/s sampling rate, as well as 8 I/O digital lines.

To read the voltages and currents of the electrical systems a hardware module was developed, comprising four voltage sensors (LEM LV25-P) and four current sensors (LEM-FLEX[®] RR3020). The current sensors offer the possibility of choosing from three scales (30 A, 300 A and 3,000 A), and it is not necessary to disconnect the electrical system that will be monitored in order to use them. The measured signals are the three phase-to-neutral voltages and the neutral-to-ground voltage, as well as the three phase and neutral currents (comprising a total of 8 signals).



Figure 1 - Developed Power Quality Monitor in an electrical panel

The Power Quality Monitor software applications were developed using the graphical programming tool LabVIEW, from National Instruments. Basically these applications allow the equipment to work as a power quality monitor or as an oscilloscope, allowing the real time visualization and storing of voltages and currents (25 ksamples/s per channel), and the calculation of True RMS values, power and energy, harmonic distortion, and other parameters. It also has the capability of producing reports and sending e-mail messages to selected destinations. The three software applications used on this power quality study are described below.

2.1 Application “Scope and THD”

This is a typical example of virtual instrumentation, as this application mimics a digital oscilloscope with 8 isolated channels (4 for voltages and 4 for currents). It includes the normal functions of a standard scope, like the time base, vertical amplifier gain, trigger setup (slope, level and source), and readouts (signal frequency, True RMS values, DC values, peak to peak values, etc). It is also possible to calculate the THD and all the individual harmonics (frequency, amplitude, and phase angle).

With this application all signals can be visualized simultaneously, with a sampling rate of 25 kHz per channel. This sampling rate can actually increase if fewer signals are being acquired. If just one channel is observed, then the sampling rate will be of 200 kHz, for two channels the sampling rate drops to 100 kHz, and so on.

It also includes the capability to automatically generate HTML and Word reports with information regarding the measured signals. Thanks to the template used, it is also possible to manipulate the data using other software tools like Matlab or Excel.

2.2 Application “PQ (Power Quality) Events”

This application acquires, in continuous mode, the three phase-to-neutral voltages (v_{an} , v_{bn} and v_{cn}), the neutral-to-ground voltage (v_{ng}), the three phase currents (i_a , i_b and i_c) and the neutral current (i_n). Simultaneously, all the necessary procedures to create strip charts, to detect sags and swells, and wave shape type anomalies, are executed every cycle, and all the important information is saved to a file.

The monitoring period is user defined, and can last between 1 minute and 30 days. In the end of the monitoring process the relevant data can be automatically sent to multiple destinations via e-mail.

2.3 Application “Classical Values”

This application calculates a number of parameters used on the analysis of an electrical system: True RMS values and phase angles for each of the acquired signals, phase impedances, voltage and current unbalance, total and displacement power factor, power (active, reactive, harmonic and apparent), active energy (kWh) and “reactive” energy

(kVARh). A phasor diagram of the voltages and currents is also plotted in real time using only the fundamental component of each of the signals.

This application has two distinct modes of operation: “Simulation” and “Acquisition”. On the “Simulation” mode all the voltage and current signals are generated by LabVIEW and all the parameters (amplitude, phase and harmonics) can be defined by the user. The “Acquisition” mode uses the values measured by the sensors.

3 POWER QUALITY ASSESSMENT

This item describes the procedures adopted for the realization of the Power Quality assessment, and presents the most important results obtained.

The first step consisted of using the application “Scope and THD” in order to correctly configure the scale of the current sensors.

Next, the monitoring period was chosen. For the first session it was selected a period of 7 days, which corresponds to one labor “cycle” of the institution. The monitor was configured to use the standard EN 50160 as a reference. This session produced a very high number of power quality events: 3,067 in total. 2,071 of these events were either sags or swells, and 996 were events related to wave shape distortion. For the second session, which lasted 3 days, the monitoring produced 443 events: 12 of these were either sags or swells and 431 were related to wave shape distortion. This session focused on a weekend and Monday morning, and is shown because of the interesting registered events.

3.1 Scope and THD Results

With the application “Scope and THD” the voltage and current signals were visualized and stored during a period of 120 ms (6 cycles). Table 1 shows the True RMS values, the crest factor values and also the THD for each signal:

Table 1 - Calculated values from measured signals

Measured Signals	True RMS values	Crest Factor values	THD (%)
v_a	232.2 V	1.38	3.1
v_b	231.5 V	1.38	2.8
v_c	231.2 V	1.39	2.4
v_{ng}	0.4 V	2.38	210.1
i_a	10.1 A	2.25	38.7
i_b	19.7 A	2.00	29.3
i_c	17.1 A	1.59	16.3
i_n	9.5 A	1.86	146.3

The set of waveforms and harmonic spectra shown in Figure 2 to Figure 11 characterize all the signals of the studied electrical system during normal working hours. This previous analysis is important to determine the scales for each individual sensor, in order to maximize the precision of the measured signals.

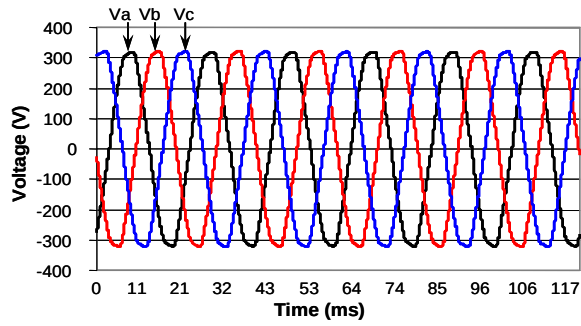


Figure 2 – Phase voltages of the system (v_a, v_b, v_c)

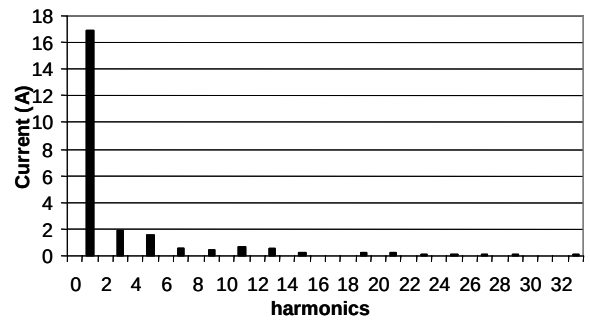


Figure 7 - THD of phase current, i_c

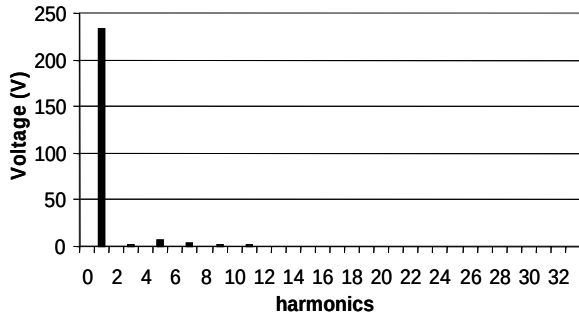


Figure 3 - THD of phase voltage v_a

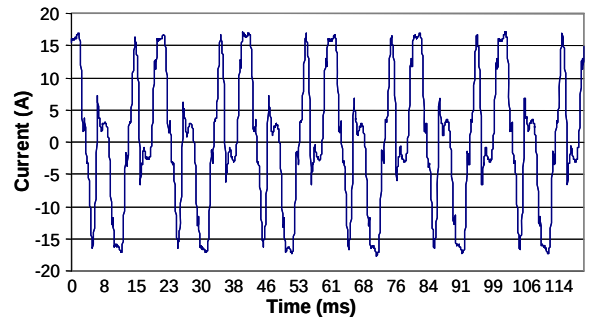


Figure 8 - Neutral current, i_n

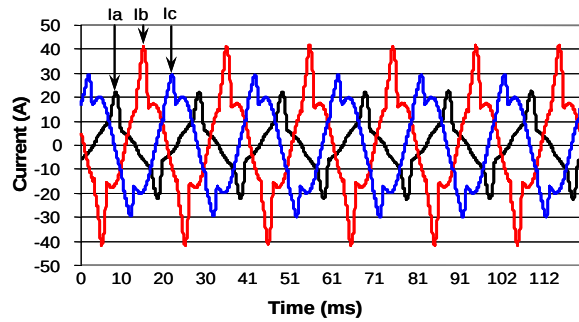


Figure 4 – Phase currents of the system (i_a, i_b, i_c)

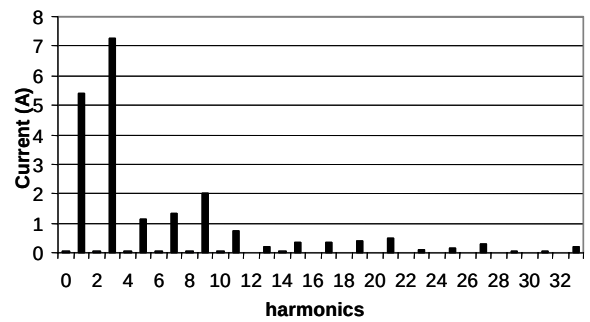


Figure 9 - THD of neutral current, i_n

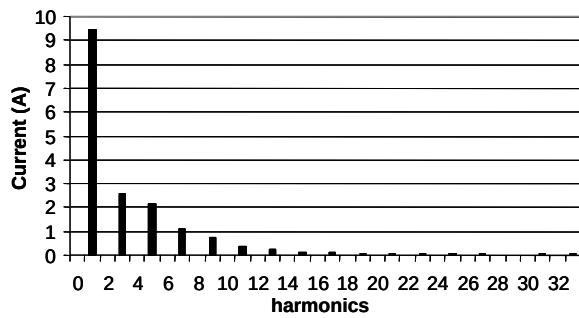


Figure 5 - THD of phase current i_a

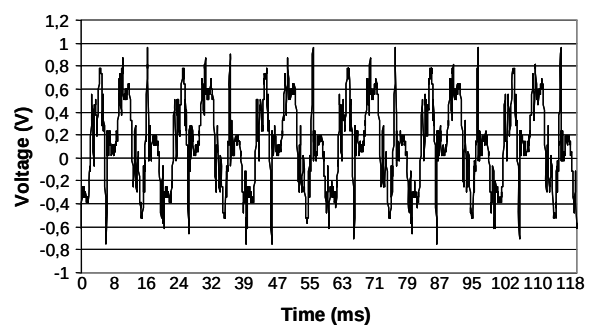


Figure 10 - Neutral-to-ground voltage, v_{gn}

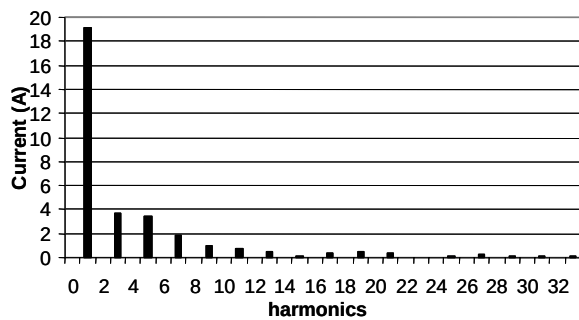


Figure 6 - THD of phase current i_b

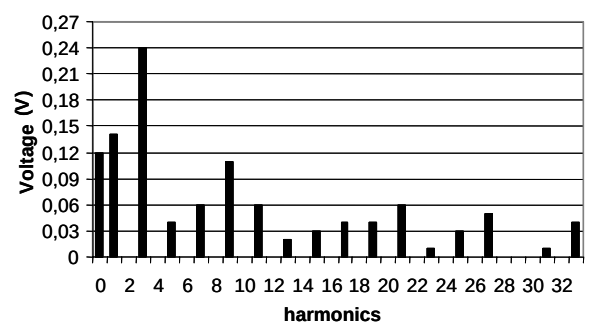


Figure 11 - THD of neutral-to-ground voltage, v_{gn}

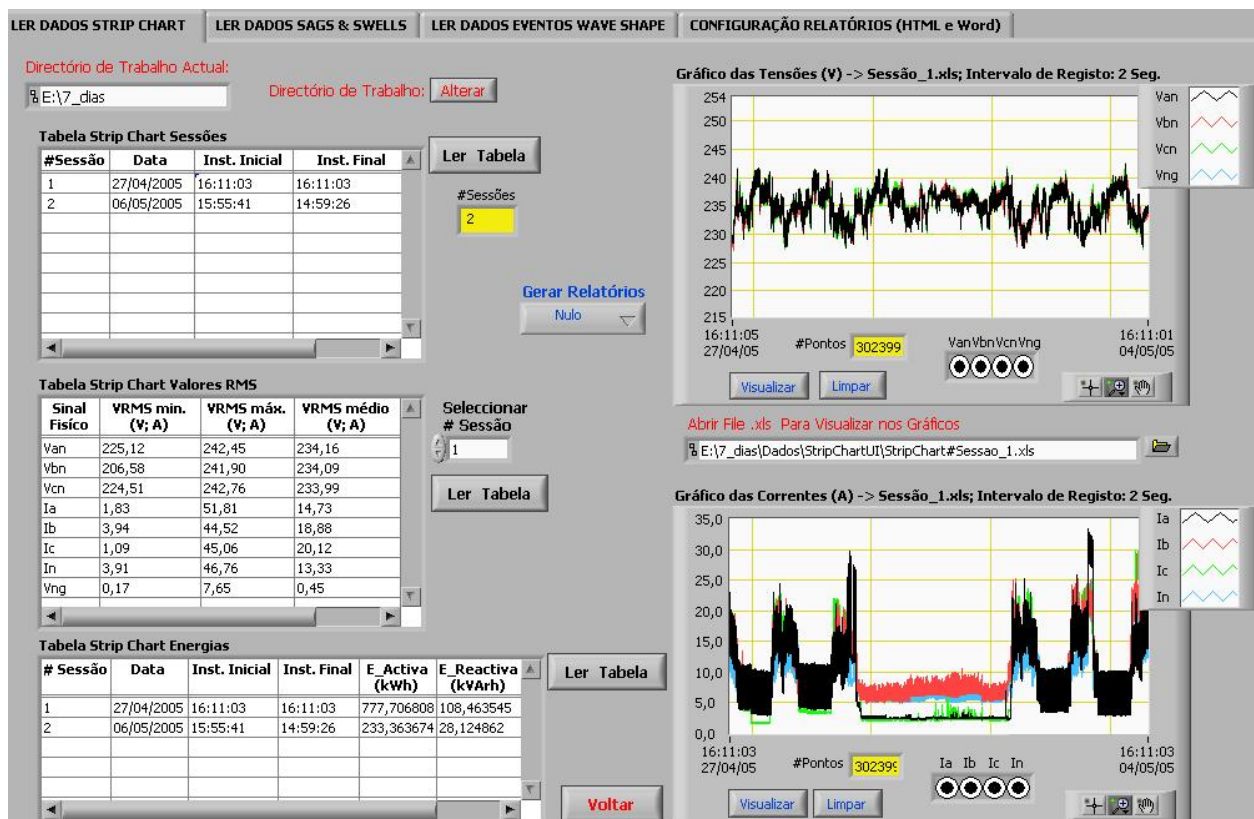


Figure 12 - Strip chart data of first session

3.2 Strip Chart Results

The Strip Chart interface allows the visualization of statistic data (minimum, maximum and average values) and the trend concerning the complete monitoring period of currents and voltages, as well as the energy consumption during this period. Thanks to the trend graphic it is possible to distinguish between the working days and the weekend, and also between the working hours and the night period.

Figure 12 shows the print screen of the strip chart interface. The trend graphics shown in this figure concern the voltages and currents of the 7 day monitoring session.

The second monitoring session recorded the tendency during the weekend and, more importantly, the connection of the loads on a Monday morning. Figures 13 and 14 show the voltage and current trends during this monitoring period.



Figure 13 - Strip chart voltages of second session

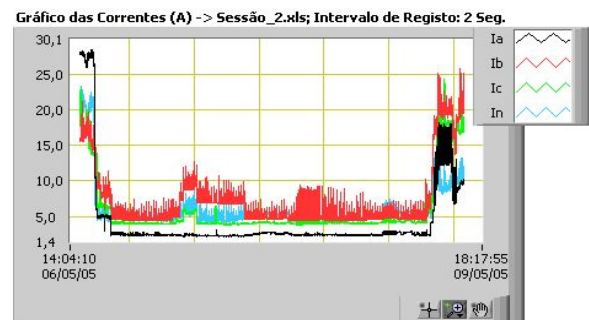


Figure 14 - Strip chart currents of second session

3.3 Sags & Swells Results

“Sags & Swells”, a module of the “PQ Events” application, registered 2,071 events during the first monitoring session. Most events were either instantaneous (up to 30 cycles) or momentary (from 30 cycles up to 3 s), according to the classification given by the EN 50160 standard. Most of the records occurred at night, when the vast majority of the loads are disconnected, and were swells (exceeding the maximum value of 242 V specified by the standard EN 50160). There were also some sags, like the one presented in Figure 15, where the RMS value in the voltage of phase *b* dropped to 207 V for three cycles. This problem occurred on day 01/05/2005 at 5h:38m:38s.

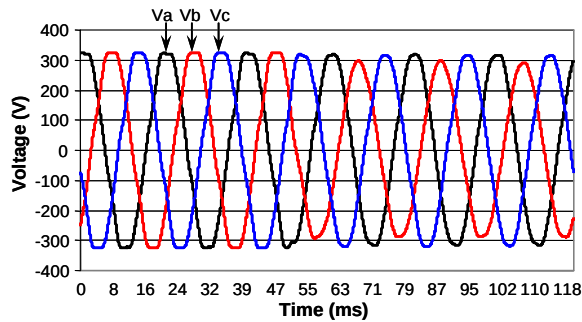


Figure 15 - Phase voltages, and sag on voltage v_b

Also during the first monitoring session, there were three swells in the neutral-to-ground voltage, v_{ng} , with values up to 8 V, when the standard allows only 5 V, and the normal value observed at the installation was only 0.6 V.

Although the second session comprised a smaller time interval, two sags were detected that could actually affect the most sensitive equipment of the installation. The first sag lasted approximately 35 cycles, was detected at 7h:50m:39s on 09/05/2005, and the RMS value of the voltages dropped to 150 V (0.65 pu). The second sag was detected on the same day, at 7h:50m:40s, lasted 13 cycles, and the voltages dropped to 167 V (0.73 pu). Figures 16 and 17 refer to the second event.

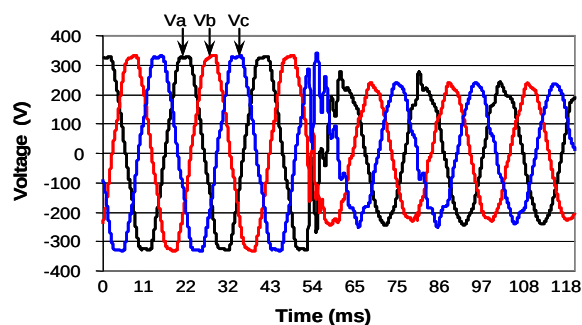


Figure 16 - Beginning of sag event

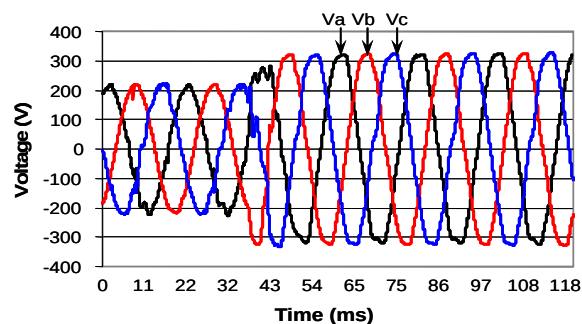


Figure 17 - End of sag event

3.4 Wave Shape Results

During the first session, 996 events of the type “Wave Shape” were registered. Most of these events are slight transient disturbances, and the remaining ones are sags, swells or unbalance, which are also registered by this module.

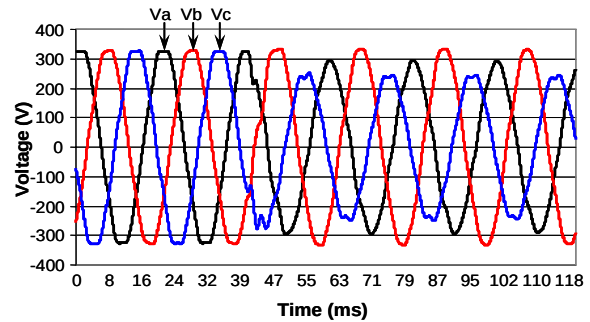


Figure 18 - Voltage unbalance

During the second session there was a considerable voltage unbalance (26%), that preceded the previously referred voltage sag, which lasted 13 cycles. The unbalance can be visualized in Figure 18.

4 CONCLUSION

This paper described the main characteristics of a developed Power Quality Monitor, and its capabilities. This equipment was used in a power quality assessment, and the most interesting power quality cases registered during the monitoring sessions were shown. The obtained results demonstrate the importance of having a power quality monitor continuously operating, especially in installations where power quality is a key factor for an industrial process. Some problems may have dire consequences, like malfunctions or interruptions in the operation of equipment, which might lead to a decrease in productivity, leading to economic losses.

The power quality monitor provides the user with information regarding the types of problems occurring at the installation which, in turn, can lead to pinpointing and solving those problems.

ACKNOWLEDGEMENT

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