International Journal of Energy Engineering 2017, 7(3): 79-89
DOI: 10.5923/j.ijee.20170703.03

Modern Techniques for Power Quality Analysis Using LabVIEW Environment

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Abstract This paper presents a case study for monitoring the quality of electric energy in an industrial manufacturer of technical rubber and reclaimed rubber products. The measurements were carried in the power supply point where the quality of the electric energy is influenced by the activity of the manufacturer, the transmission and distribution provider, the supplier as well as the electric power consumer activity. Transients occur at this limiting point, with negative effects on the consumer, as well as on the electric power supply network. Quality indicators of electric energy, depending on the place of occurrence of disturbances are indicators of primary and secondary quality indicators. The data processing was achieved using LabVIEW software in terms of the two types of quality indicators. A software application was made to allow reading of files and processing them (creation of data tables and charts). Based on the data obtained from the measurements and using the interface created in LabVIEW, it was possible to carry out the analysis of the average hourly consumption, the power factor, the wave forms of the current and voltage, the analysis of the current and voltage harmonics. The software application enables creation of customized reports with varying ease of use and flexibility. Using the software application developed in LabVIEW, full quality analysis of electric energy can be done at the user's premises.

Keywords Quality analysis, Electric energy, LaVIEW environment

1. Introduction

The quality of the electric energy is influenced by the activity of the manufacturer, the transmission and distribution provider, the supplier as well as the electric power consumer activity. The operation of industrial users can be accompanied by the input of significant disturbances in the electric power supply network in the form of voltage fluctuations, voltage dips and swells, unbalance which can translate into a reduction in the quality of electricity supplied to the consumers connected in the network [1].

An incident in any of these grids can lead to an interruption in the supply and/or dips that - depending on the structure of the grid - can produce effects on consumers and producers connected in a same power supply points and even further. An incident in the facilities of a manufacturer or a consumer may lead to a transient that would affect all consumers connected at the same power supply points [2, 3].

Quality indicators of electric energy, depending on the place of occurrence of disturbances are indicators of primary and secondary quality indicators [1].

The quality of electric energy – is assessed using quality indicators for specific electrical quantities, voltage, frequency and respectively for the electricity supply utility in terms of the duration of power failure. The quality indicators are determined at the limiting points between the electric wiring of the supplier and of the consumer which constitute the load:

- primary quality indicators (power supply frequency variations, voltage variations, dips, power failure, temporary surges, transients) are given by the production, transport and distribution of electric energy;
- secondary indicators (harmonics, interharmonics, voltage fluctuations, unbalances) are given by the disruptive operation of industrial consumers [1, 4-9].

The values accepted for most quality indicators are standardized by energy standards and prescriptions. According to the standard of performance for the electricity supply utility with regulated tariffs the supplier has the obligation to meet the parameters of electric energy quality [10, 11].

Based on these considerations and according to present laws of energy efficiency the industrial consumers are obliged to carry out an energy balance once every four years [12].

In order to improve quality evaluation of energy to industrial consumers, we proposed a specialized software developed in LabVIEW that allows reading of measured data obtained from a network analyzer (in this case CHAUVIN

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Published online at http://journal.sapub.org/ijee

ARNOUX - CA 8352), processing data to create a clear picture about the quality of electric energy in an industrial consumer.

The LabVIEW is a programming environment based on G language (graphic language) core intended mainly to develop applications for data control and acquisition, their analysis and results presentation [13-16].

LabVIEW contains a comprehensive set of tools for acquiring, analysing, displaying, and storing data, as well as tools to help you troubleshoot the code you write [17].

This paper presents a case study for monitoring the quality of electric energy in an industrial consumer using a software application developed in LabVIEW.

2. Measurement Method

The energy measurements carried out on the audited outline (fig. 1) were based on the use of the following three phase power analyser - CA 8352 power analyser [18].

The audited outline is presented in Figure 1.

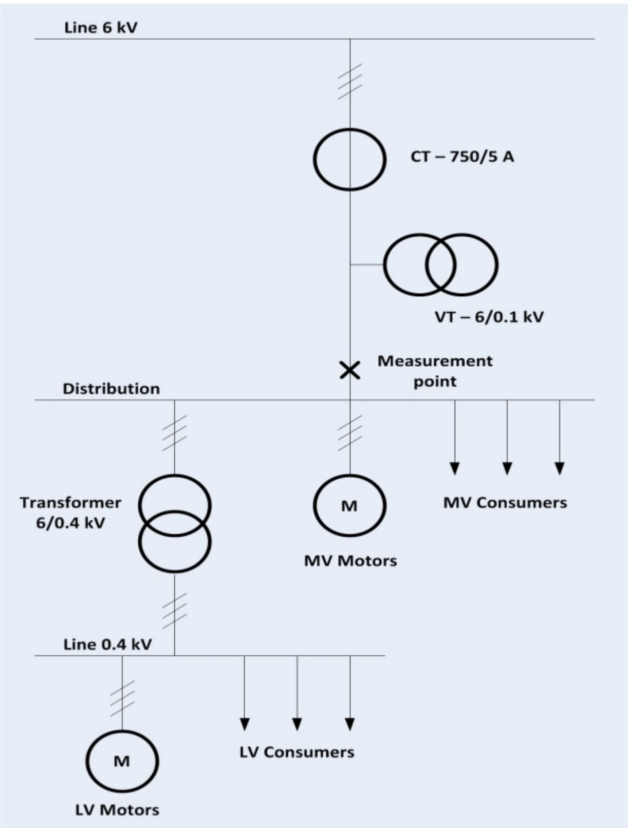

Figure 1. Single-wire electrical circuit diagram

The measurements were carried in the power supply point of an independent contour.

The C.A 8352 is an electrical network analysis instrument (harmonics, power, EN 50160, flicker, etc.), easy to use, this instrument can be programmed and read at the touch of the screen, in the particularly user-friendly Windows environment, includes FFT analysis functions and an oscilloscope mode for displaying curves. The instrument's configuration is defined by the user according to the option chosen: “RMS hp” (half-period) power analysis/ monitoring of minimum, maximum and average values calculated over a half-period (i.e. 10 milliseconds) during the integration period defined; flicker measurement/ EN 50160 standard analysis; recording of transients; data logger: analogue data recording; location and recording of control and remote control signals; “Symmetry” option displaying the direct, indirect and homopolar values in U and I and indicating the unbalance of the system in terms of voltage and current/measurement and monitoring of load and short-circuit impedances on each phase of the electrical grid; remote communication via ETHERNET of the various graphic screens and the data recorded [19].

3. Description of the Software

The ability to analyse, interpret and manipulate data is a fundamental need in many scientific and engineering applications. LabVIEW provides built-in analysis capabilities in an integrated environment, enabling to obtain results faster. LabVIEW is the tool of choice due to its unparalleled connectivity to instruments, powerful data acquisition capabilities, natural dataflow-based graphical programming interface, scalability, and overall functional completeness. One need that persists regardless of the area of expertise is the fact that users must manipulate data and measurements, and make decisions based on it.

The CA 8352 has a software package allowing the user to download the data stored in the internal storage to a PC and using an interface developed LaVIEW, full quality analysis of electric energy can be done at the user's premises. The LabVIEW is often viewed primarily as a measurement tool, but it also provides powerful analysis libraries, routines, and algorithms that range from basic math to advanced signal processing which can be easily integrated into any LabVIEW program. The stages of the analysis achieved using the software application for the measured data of quality indicators consist of loading text files, processing, achieving graphs with their evolution in time and generating excel type reports.

According to the analysis stages the main structure used to develop the software application is flat sequence structure. Data flow for the flat sequence structure differs from data flow for other structures. Frames in a flat sequence structure execute from left to right and when all data values wired to a frame are available. The data leaves each frame as the frame finishes executing. This means the input of one frame can depend on the output of another frame.

3.1. Description of the Software for Primary Quality Indicators

The software application presented in Figure 2 is used to perform reading of text files from the results of measurements carried out using the network analyser for primary quality indicators. The primary quality indicators that we process are voltage, current, active power, reactive power, apparent power, power factor, active energy and reactive energy.

Figure 3 shows a part of the application software block diagram with the function that performs reading from text files to be processed mathematically. The minimum, average and maximum values of the primary quality indicators are determined and the graphs for the evolution in time are achieved for each quality parameter with the whole set of recordings, as noticed in the software interface.

Figure 4 and 5 show a part of the block diagram of the application software with the table result from processing data and the report generation of the measured data. The first table contains measured data with date and time properly.

Figure 6 and 7 show a part of the block diagram of the application software with the second table which contains the minimum, average and maximum of the measured data and the report generation.

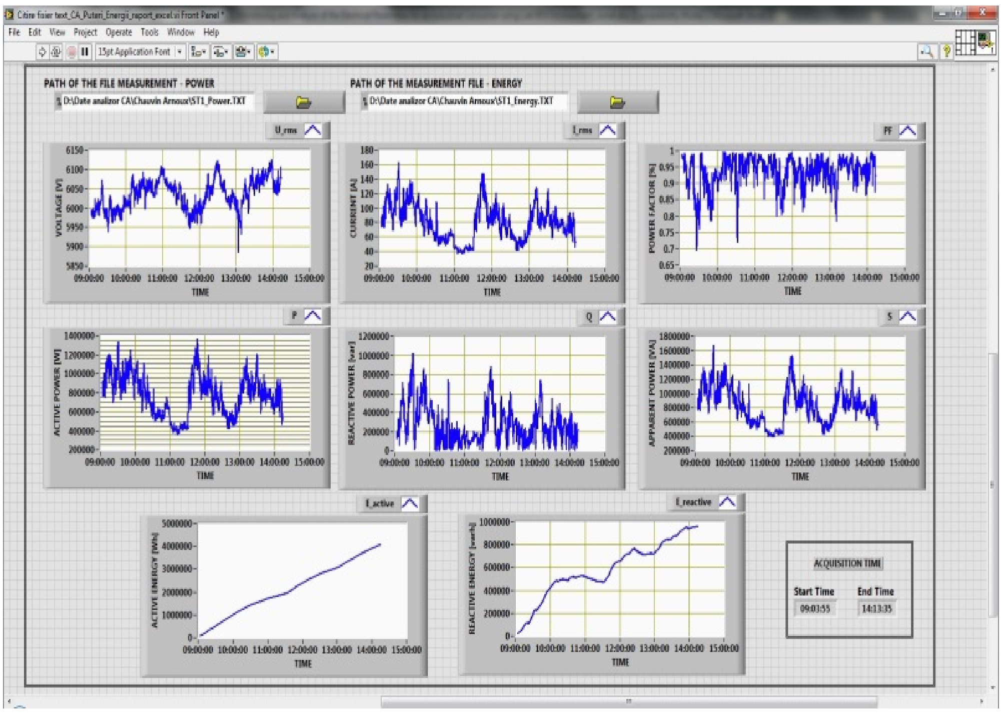

Figure 2. The software interface for power quality

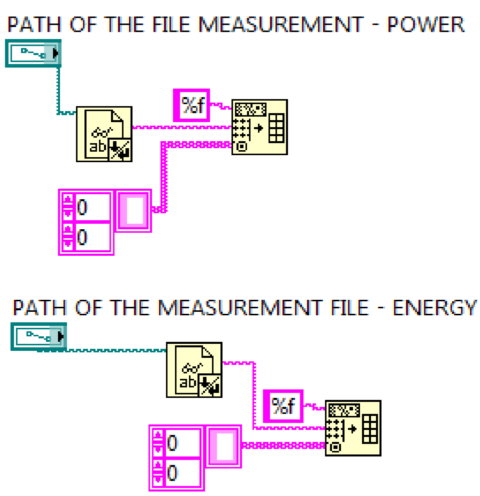

Figure 3. Read from text file function

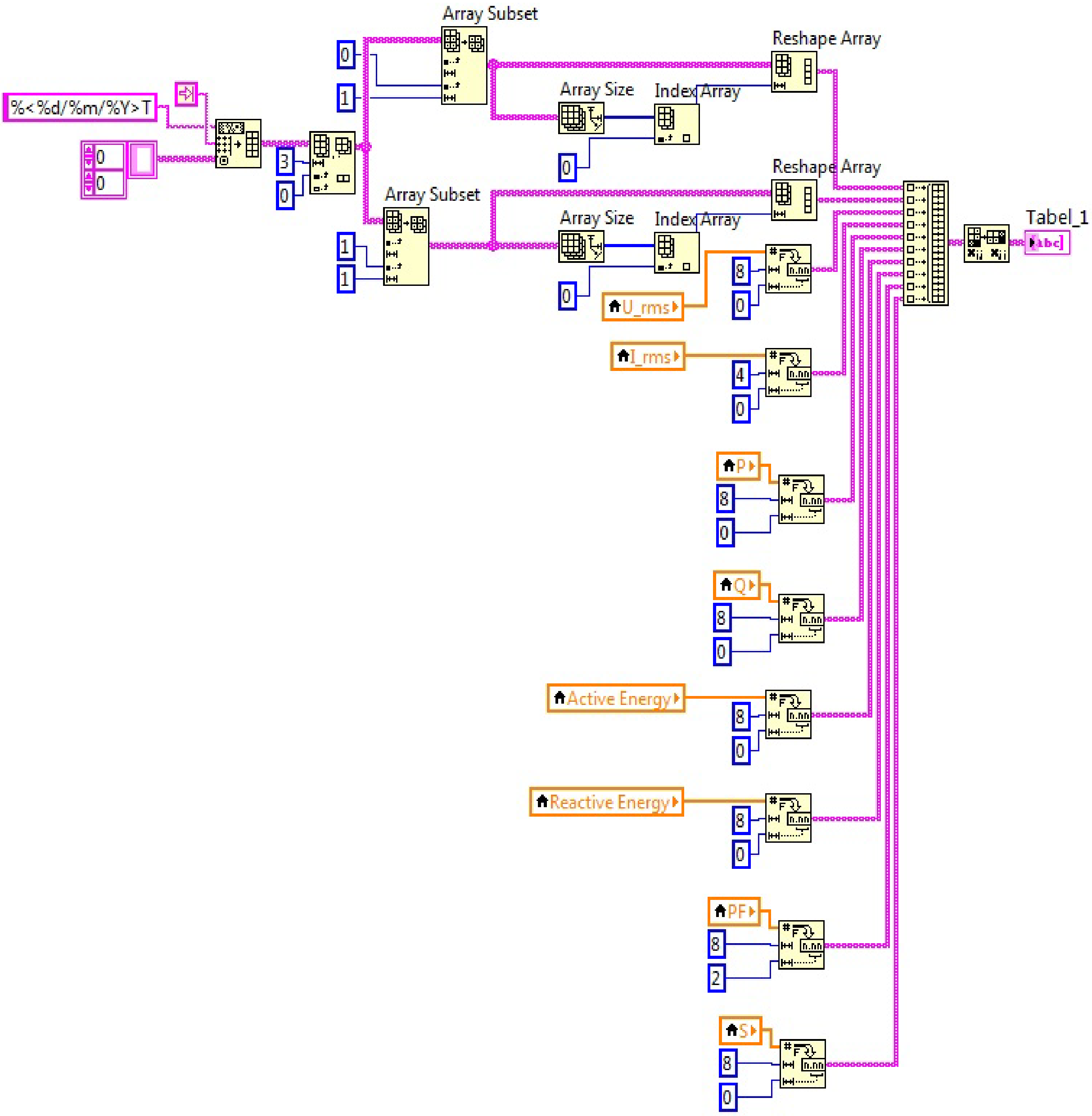

Figure 4. Build table with measurement data

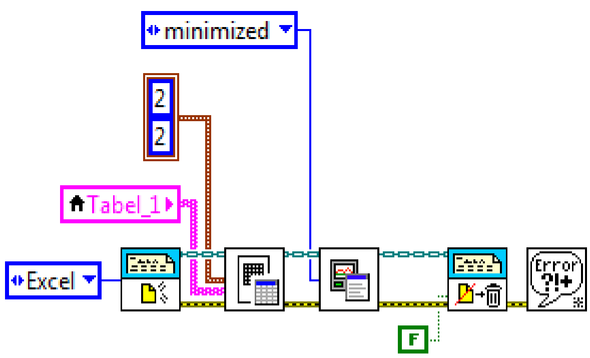

Figure 5. Generate excel report for measured data with date and time properly

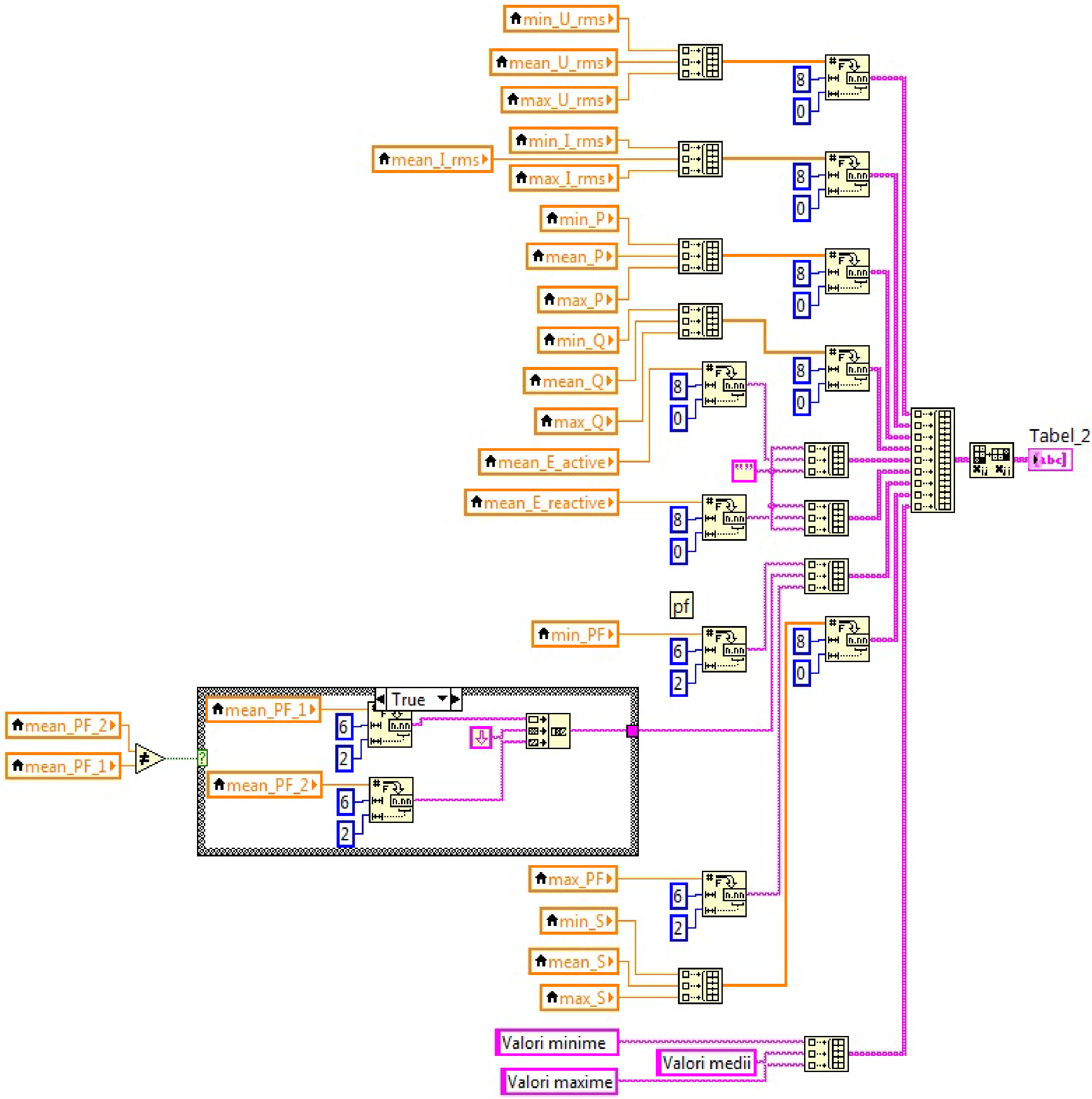

Figure 6. Build table with processed data

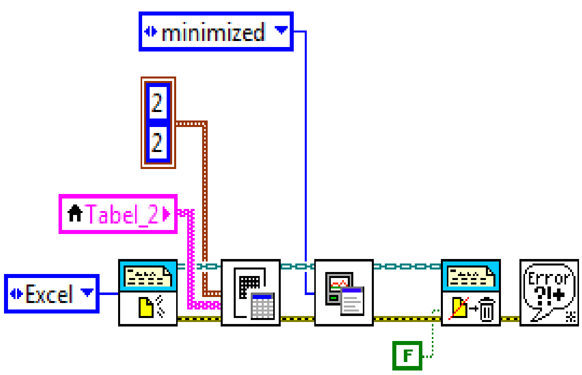

Figure 7. Generate excel report with the processed data

3.2. Description of the Software for Secondary Quality Indicators

The software application presented in Figure 8 is used also to perform reading of text files from the results of measurements carried out using the network analyser for secondary quality indicators. The secondary quality indicators that we process are individual current harmonics, individual voltage harmonics, the total harmonic distortion for current and the total harmonic distortion for voltage.

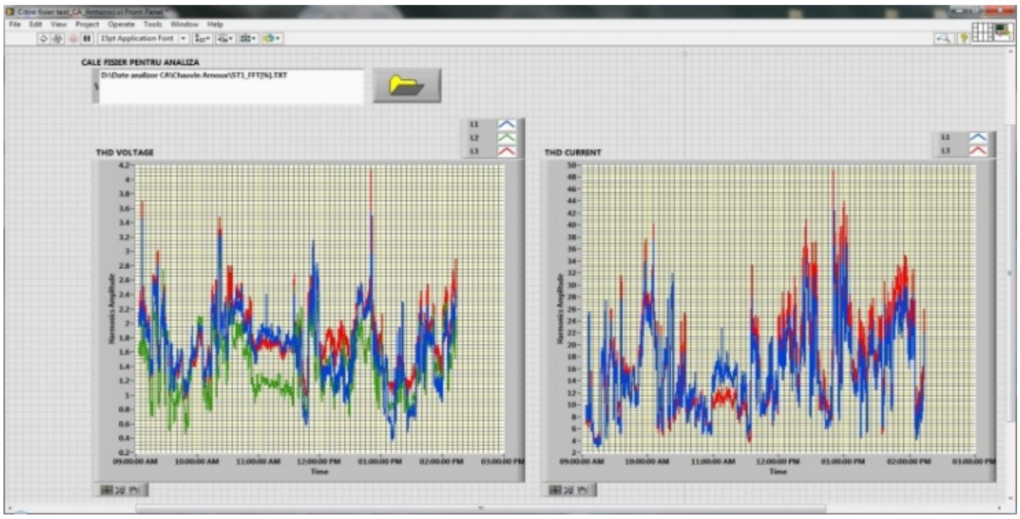

Figure 8. The software interface for harmonic analysis

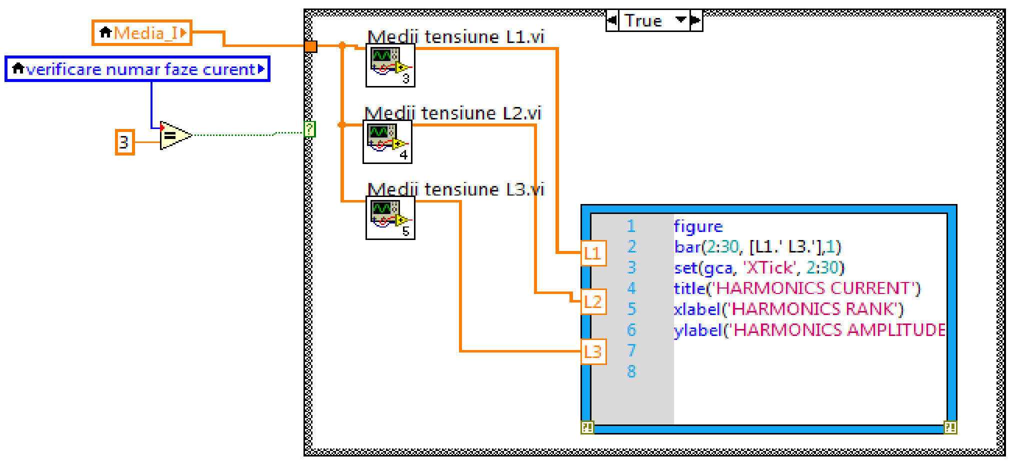

Figure 9. Plot of the bar graph with harmonics

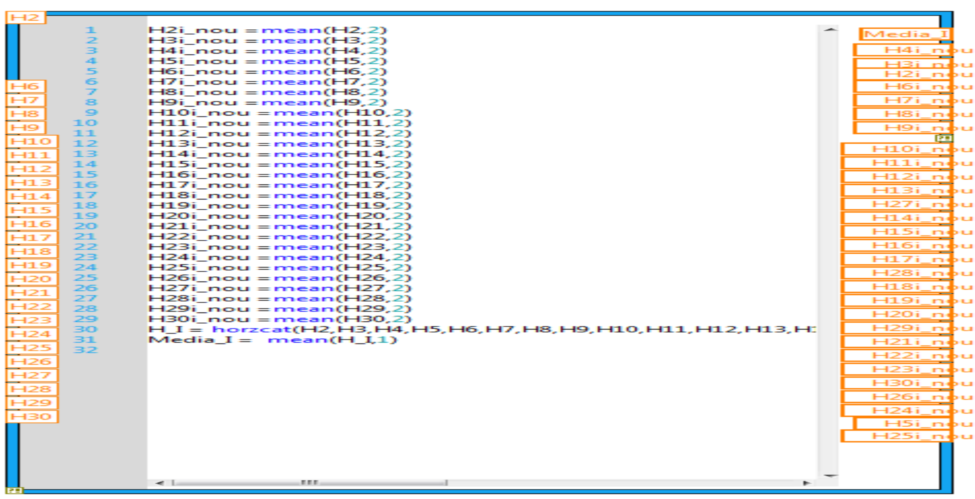

Figure 10. MathScript Node for calculating means of columns and rows

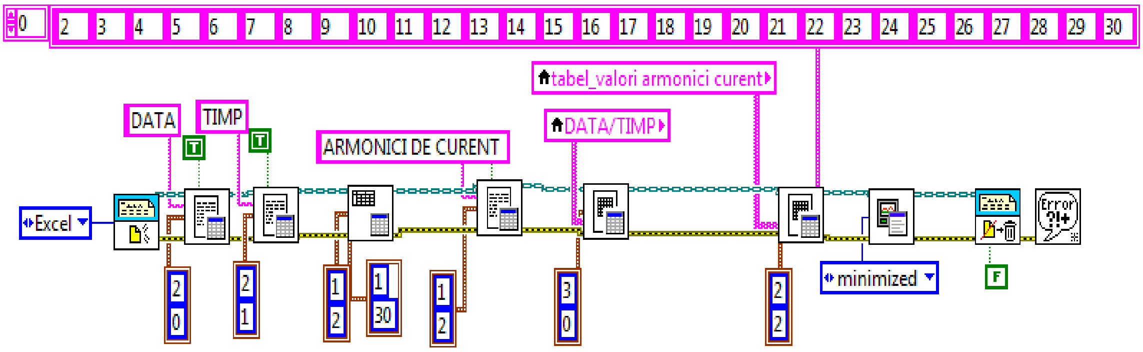

Figure 11. Generate excel report with individual current harmonics

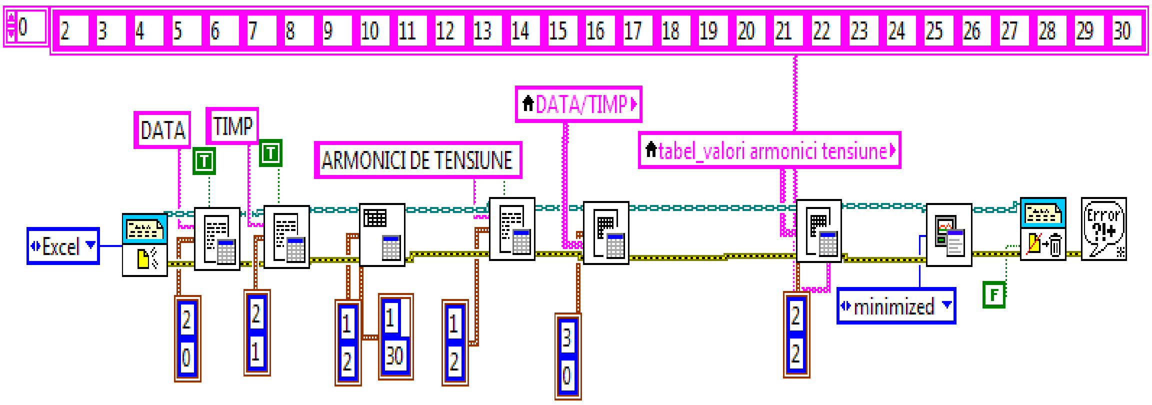

Figure 12. Generate excel report with individual voltage harmonics

LabVIEW MathScript RT Module adds math-oriented, textual programming to LabVIEW. The MathScript Node offers an intuitive means of combining graphical and textual code within LabVIEW, both are currently used in a number of science, engineering and technology programs and industries for simulation and analysis [20-23].

Figure 9 shows the MathScript node for plotting bar graph with harmonics and Figure 10 show MathScript node for calculating means of columns and rows.

Figure 11 and 12 shows a part of the block diagram of the application software with the excel report generation with individual current harmonics and individual voltage harmonics.

4. Results Obtained with LabVIEW Software Application

The measurements were carried out at the level of 6 kV on the outgoing circuit on the consumer switchboard, with a 5 seconds sampling rate of measurements.

Processing the measured data in LabVIEW revealed the following charts for the evolution in time of the data resulting from measurements:

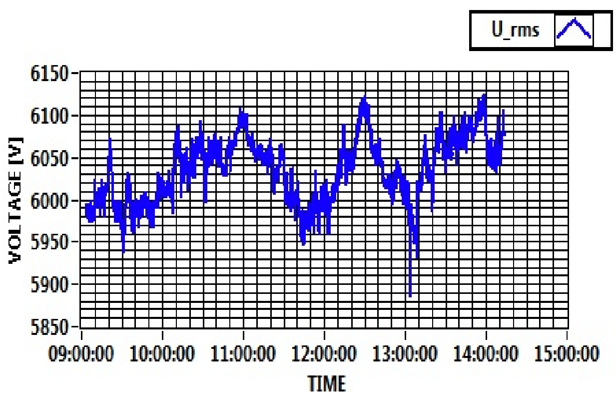

Figure 13. Time evolution of voltage

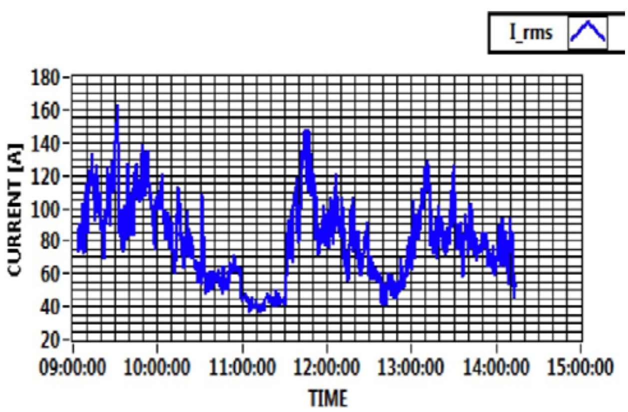

Figure 14. Time evolution of current

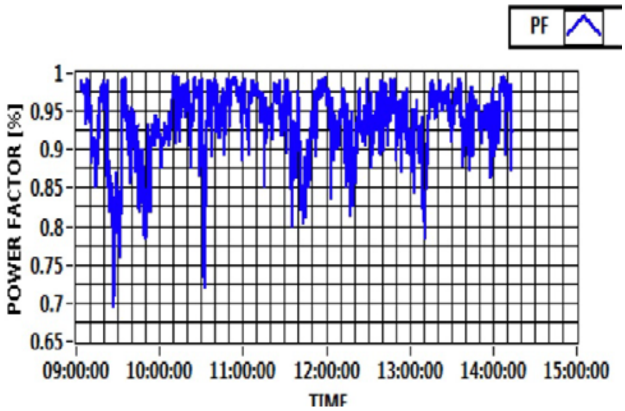

Figure 15. Time evolution of power factor

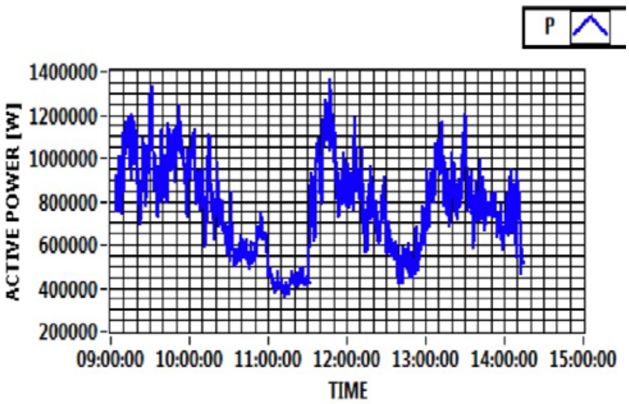

Figure 16. Time evolution of active power

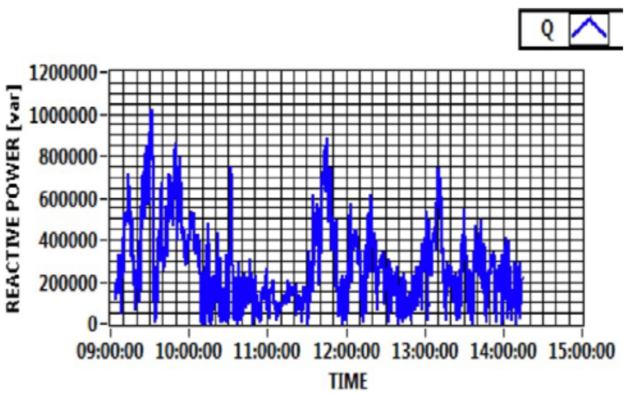

Figure 17. Time evolution of reactive power

Table 1. Summary of measured average hourly levels of consumption

Measurement point	Power supply of consumer
Voltage (V)	6126
Current (A)	163
Active Power (W)	1364099
Reactive Power L (var)	1022143
Active Energy (Wh)	771800
Reactive Energy (varh)	181109
Apparent Power (VA)	1676549
Power Factor	0.95

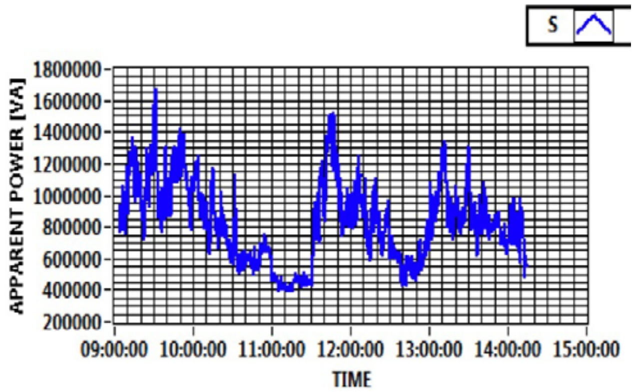

Figure 18. Time evolution of apparent power

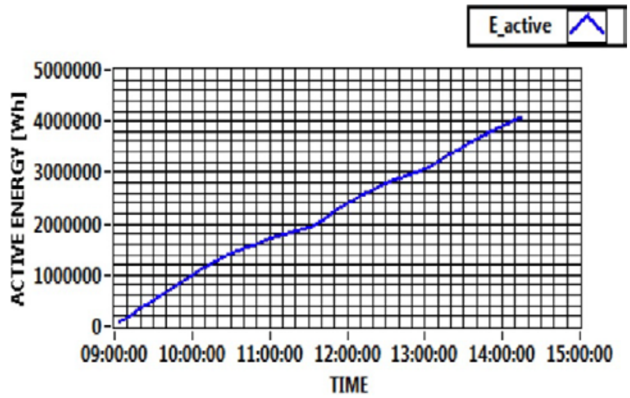

Figure 19. Time evolution of active energy

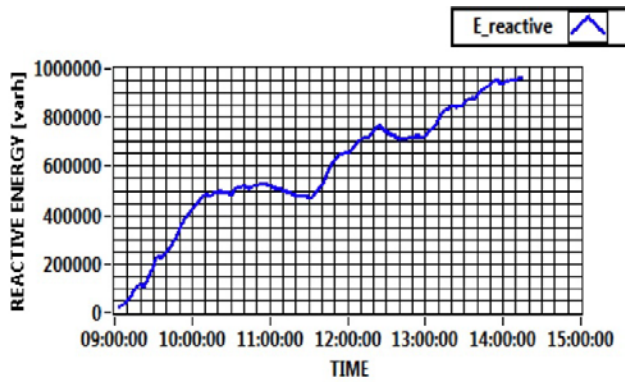

Figure 20. Time evolution of reactive energy

Table 2. The harmonic distortion condition

Circuit	General Power Distributor 6 kV
Total harmonic current distortion factor -THD_I (%)	16,66
Total harmonic voltage distortion factor -THD_U (%)	1,63
Individual current harmonics (%)	5 – 14,5 % 7 – 5,4 %
Individual voltage harmonics (%)	5 – 1,2 % 7 – 1,05 %

Processing the measured data in LabVIEW revealed the following charts for the evolution in time of the data resulting from measurements:

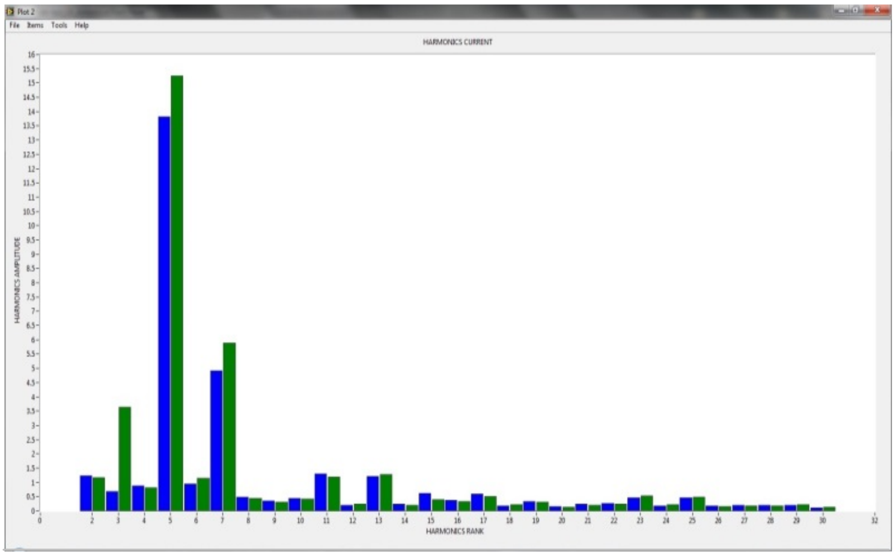

Figure 21. Individual current harmonics

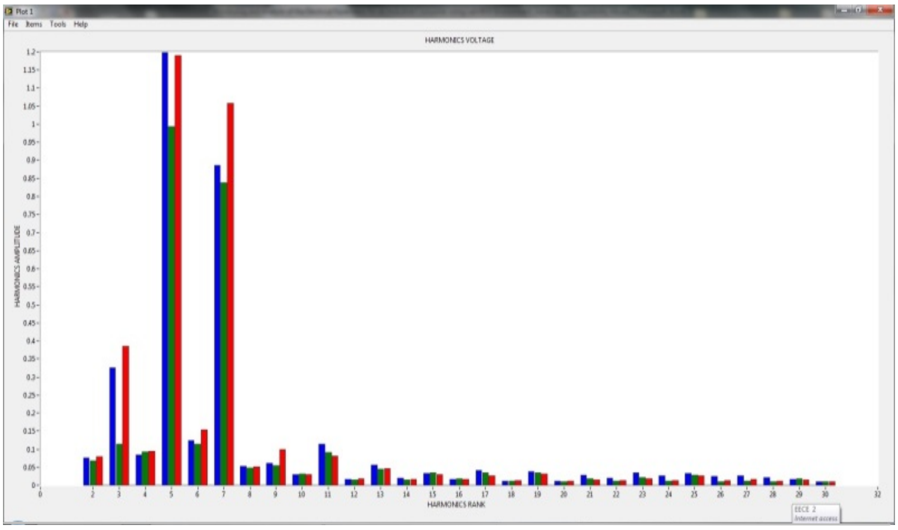

Figure 22. Individual voltage harmonics

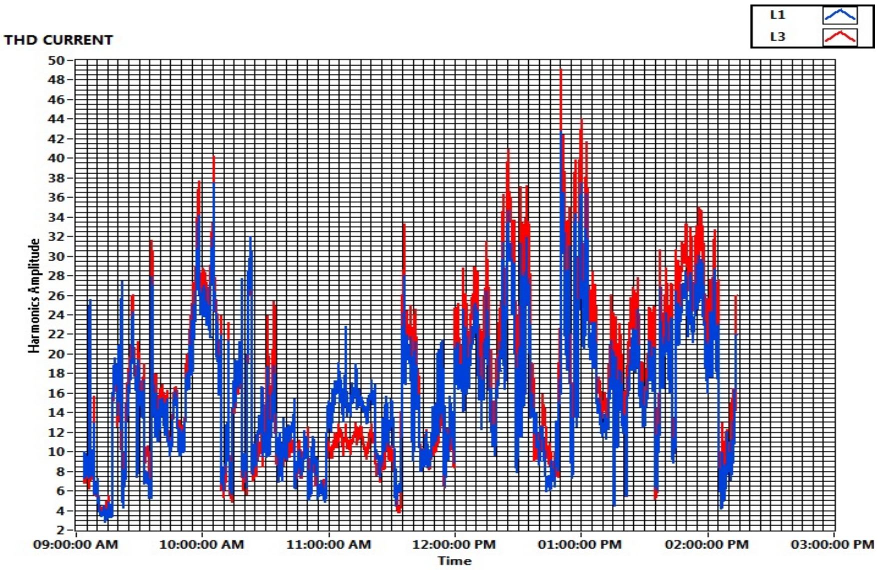

Figure 23. Total harmonic current distorsion factor -THD_I

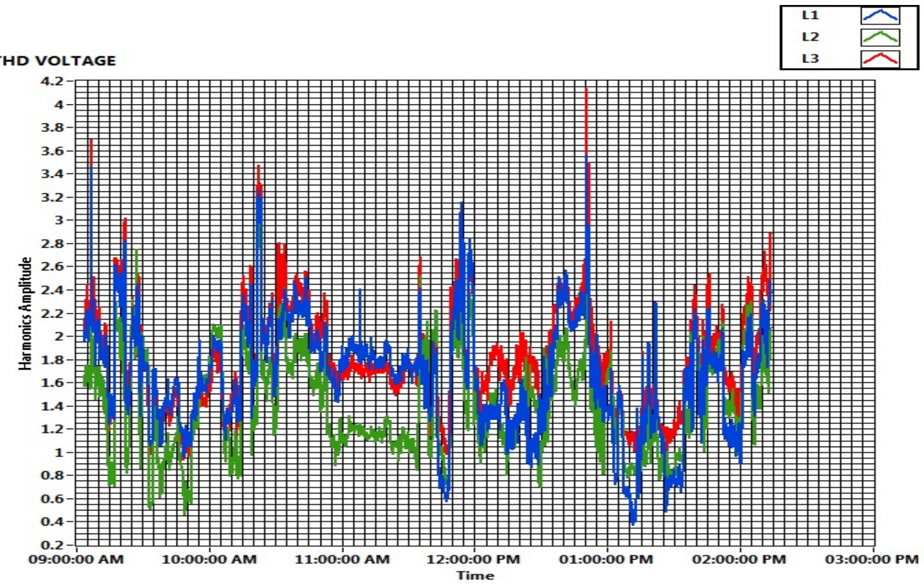

Figure 24. Total harmonic voltage distorsion factor -THD_U

From the data analysis we can conclude the following:

- in power factor metering point average is 0.95 (see Table 1), situated across the neutral value (0.90);
- the total harmonic current distortion factor (THD_I) in the 6 kV power supply point has a high average value of 16,66% (see Table 2 and Figure 21) and exceeds the 15% required by the IEEE 519/2014-16 for ratio ISC/Iload=100÷1000;
- the presence of 5^{th} harmonic, around the 15% limit set, alters the current waveform at the metering point;
- the total harmonic voltage distortion factor (THD_U), in the 6 kV power supply point has a high average value of 1,63% (see Table 2 and Figure 22) and does not exceed the 8% required by the IEEE 519/2014-16;
- inside the balance outline of one of the circuits of the non-linear consumers, the gravity of harmonics 5 and 7 is higher and it alters the current waveform, and the total current harmonic distortion factor has high values which exceed the set limits;
- in the Figure 21 it may be observed that harmonic 5 (14,5%) and harmonic 7 (5,4%) had the highest values of the current harmonics;
- in the Figure 22 it may be observed that harmonic 5 (1,2%) and harmonic 7 (1,05%) had the highest values of voltage harmonics.

5. Conclusions

The software application realised and presented in this paper starts from the problems caused by harmonic currents overloading of the working neutral, overheating of the transformers, unexpected operation of the circuit breakers, overload of capacitors for power factor correction, Kelvin effect in conductors.

The software application developed in LabVIEW allows reading of measured data carried out using the network analyser, processing data to create a clear picture about the quality of electric energy in an industrial consumer, achieving charts and their evolution in time, as well as generating word-based files containing the processed data.

It was possible to carry out the analysis of the average hourly consumption, the power factor, the wave forms of the current and voltage, the analysis of the current and voltage harmonics.

Data obtained from the processing program developed in LabVIEW allows a detailed analysis of the status of the measured system. The software application follows the user’s requirements and facilitates the analysis of power quality at industrial consumer.

Future works will analyse the possibility of installing power-line active filters to reduce 5^{th} and 7^{th} harmonics and to meet the standards on negative non-symmetrical and distorting condition in electrical networks.

ACKNOWLEDGEMENTS

The paper was developed with funds from the Romanian Ministry of Education and Scientific Research as part of the NUCLEU Program: PN 09 01 01 27.

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