Monitoring and Analysis of the Electrical Parameters for an Industrial Consumer using LabVIEW Environment

Claudiu-Ionel Nicola, Viorica Voicu, Sebastian Popescu, Maria Cristina Niţu, Daniela Iovan, Marian Duţă, Alin Benea, Silviu Andreescu
ICMET Craiova / Research, Development Division for Electric Equipment and Energy Efficiency, Craiova, Romania, nicolaclaudiu@icmet.ro

***Abstract* - This[1] paper presents a case study for monitoring the quality of electric energy in an industrial consumer. 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. There are two types of electric energy quality indicators, depending on the point of occurrence. Primary quality indicators are given by the production, transport and distribution of electric energy. Secondary indicators are given by the disruptive operation of industrial consumers. The data processing was achieved using LabVIEW software in terms of the two types of quality indicators. 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, consumer, LaVIEW environment.*

I. 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].

[1] The paper was developed with funds from the Ministry of Education and Scientific Research as part of the NUCLEU Program: PN 09 01 02 27.

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

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 [4-7].

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, approved by ANRE's decision no. 34/1999, the supplier has the obligation to meet the following parameters of electric energy quality [8], [9]:

- frequency: during 95% of the week, the frequency must be within the range 50 Hz ± 1% and during 100% of the week, within the range 50 Hz + 4% up to 50 Hz 6% ;

- voltage: during 95% of the week, the voltage mustn't have higher deviations than ±10% of the contracted voltage. In case you are dissatisfied with the quality of the electricity, you have the right to challenge this to the provider, who has the obligation to check the quality parameters, to analyze together with the supplier solutions for providing the stipulated quality level, reporting the results of the analysis carried out and the actions that were taken.

In case of voltage deviations higher than ±10% of the contracted voltage, during 95% of the week, and if the contracted frequency exceeds the 50 Hz ± 1% range, during 95% of the week, and the range of 50 Hz + 4% up to 50 Hz 6%, during 100% of the week, you are entitled to a reduction in tariffs. The amount of tariff reductions for households is of 1% for each deviation percentage outside the stipulated quality limits.

Based on these considerations and according to Law 121/2014 on energy efficiency, industrial consumers are obliged to carry out an energy balance once every four years.

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 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. LabVIEW contains a comprehensive set of tools for acquiring, analyzing, displaying, and storing data, as well as tools to help you troubleshoot the code you write [10-14].

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

II. Measurement Method

The energy measurements carried out on the audited outline presented in Fig. 1 were based on the use of the following three-phase power analyzer - CA 8352 power analyzer [15].

The audited outline is presented in Fig. 1

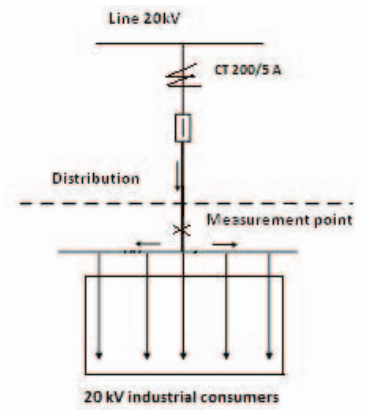

Fig. 1. Single-wire electrical circuit diagram.

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 ms) 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 [16].

III. Description of the Software

The ability to analyze, 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 function 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 network analyzer 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 as primarily 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.

A. Description of the software for primary quality indicators

The software application presented in Fig. 2 we used for performs reading of text files from the results of measurements carried out using the network analyzer 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.

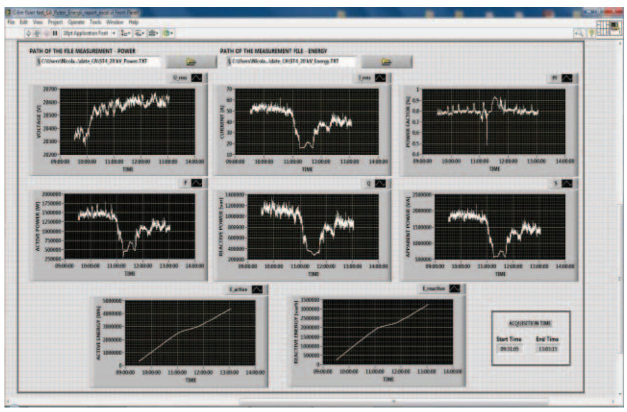

Fig. 2. The software interface for power quality.

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.

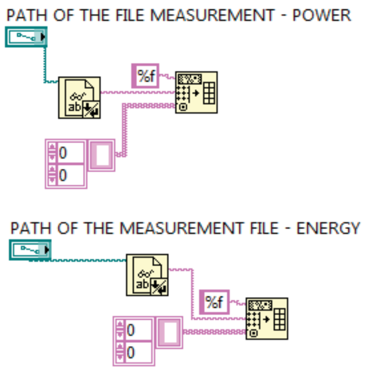

Fig. 3. Single-wire electrical circuit diagram.

Every report generation program is based on the same model. New Report.vi must be called to specify the report type (standard, HTML, Word, or Excel), and we can then populate the report with data using the VIs from the report generation function palette. Once we have completed the report, we can print, save, or e-mail it. We must close all the references at the end of the program with the Dispose Report VI.

Fig. 4 and Fig. 5 shows 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.

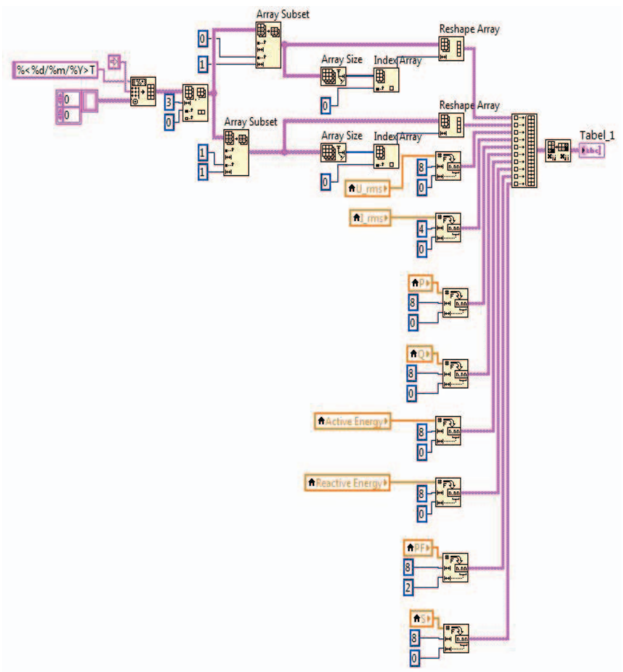

Fig. 4. Build table with measurement data.

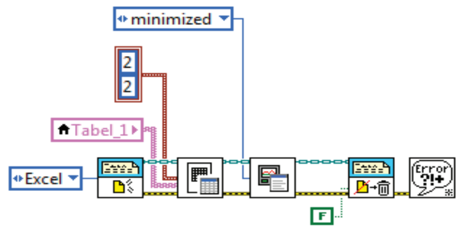

Fig. 5. Generate excel report for measured data with date and time properly.

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

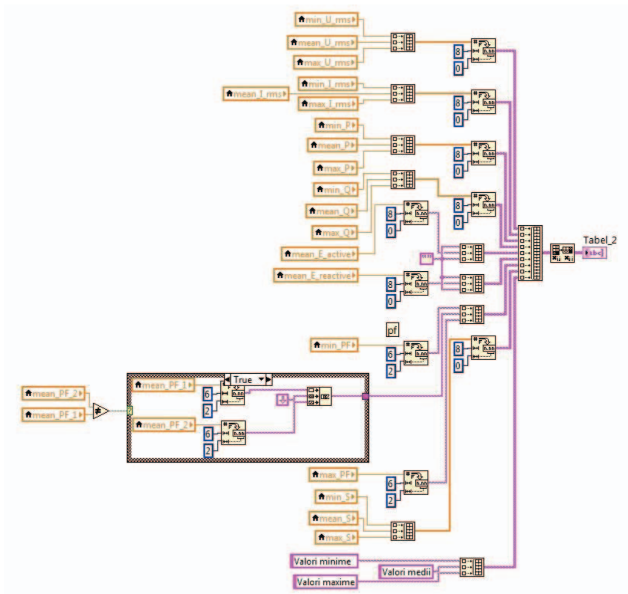

Fig. 6. Build table with processed data.

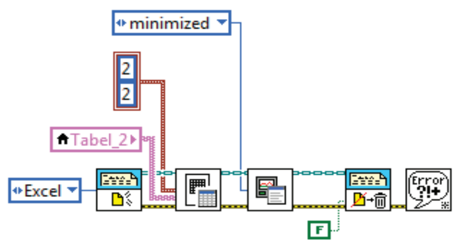

Fig. 7. Generate excel report with the processed data.

B. Description of the software for secondary quality indicators

The software application presented in Fig. 8 we used for performs reading of text files from the results of measurements carried out using the network analyzer 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.

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 [17], [18].

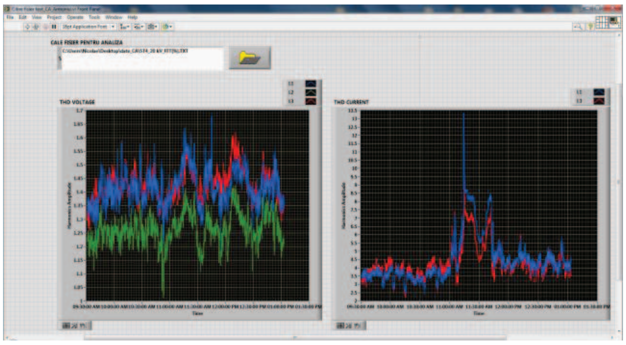

Fig. 8. The software interface for harmonic analysis.

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

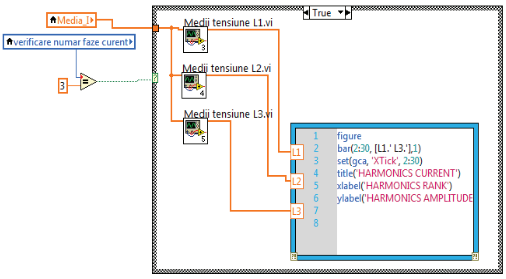

Fig. 9. Plot the bar graph with harmonics.

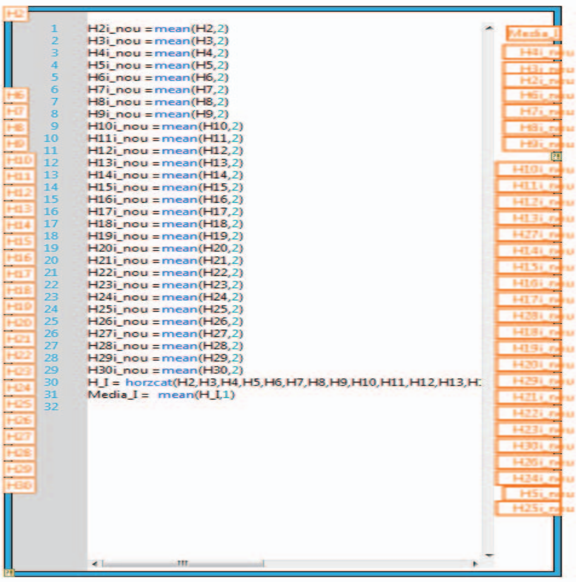

Fig. 10. MathScript Node for calculate means of columns and rows.

Fig. 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.

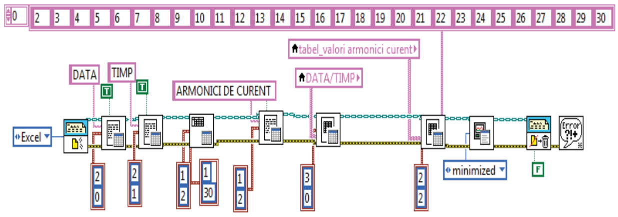

Fig. 11. Generate excel report with individual current harmonics

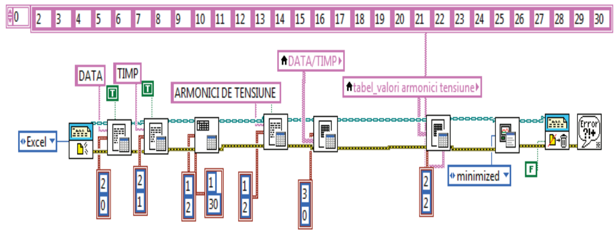

Fig. 12. Generate excel report with individual voltage harmonics.

IV. RESULTS OBTAINED WITH LABVIEW

The measurements were carried out at the level of 20 kV voltage on the outgoing circuit on the consumer switchboard, with a 5 seconds sampling rate of measurements.

The measurements were carried out at the level of 20 kV voltage 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 are:

TABLE I. SUMMARY OF MEASURED AVERAGE HOURLY LEVELS OF CONSUMPTION:

Measurement point	Power supply of consumer
Voltage (V)	20543
Current (A)	40
Active Power (W)	1142405
Reactive Power L (var)	846673
Active Energy (Wh)	1142334
Reactive Energy (varh)	846593
Apparent Power (VA)	1425421
Power Factor	0.81

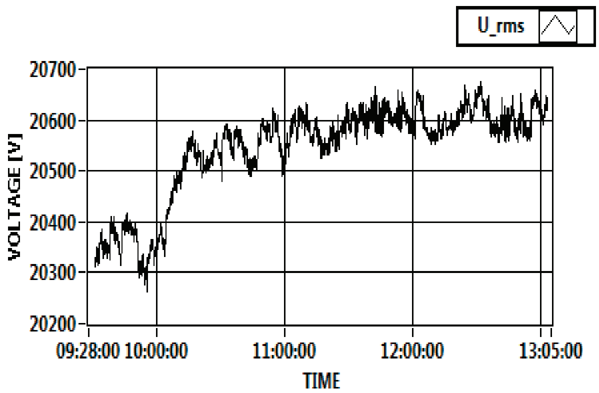

Fig. 13. Time evolution of voltage.

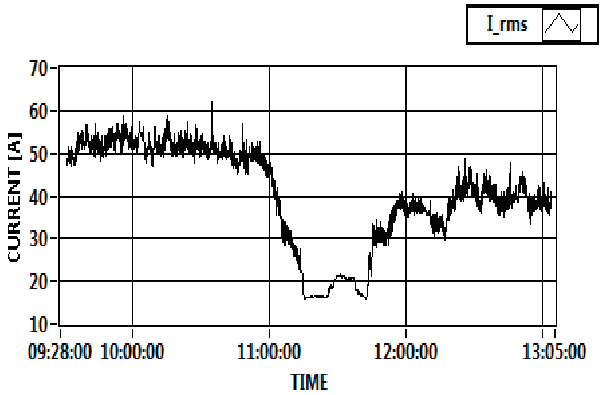

Fig. 14 Time evolution of current.

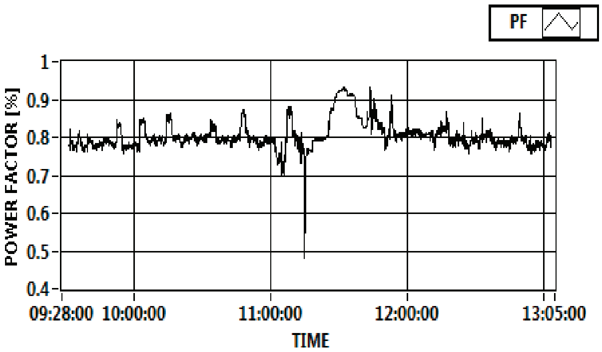

Fig. 15. Time evolution of power factor.

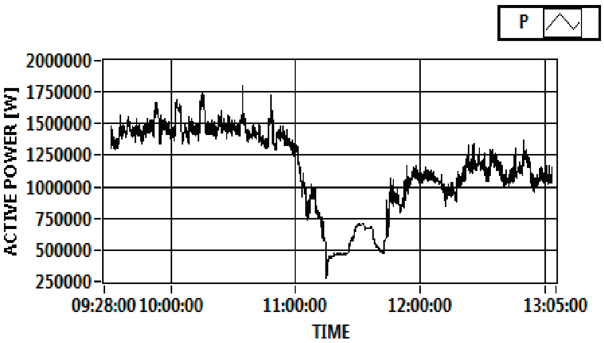

Fig. 16. Time evolution of active power.

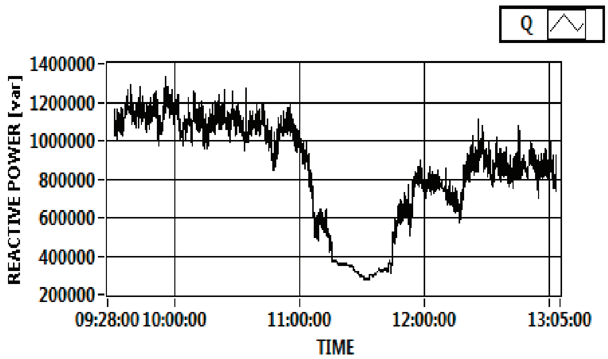

Fig. 17. Time evolution of reactive power.

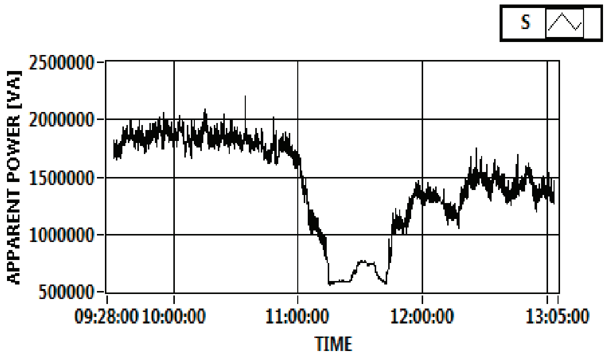

Fig.18. Time evolution of aparent power.

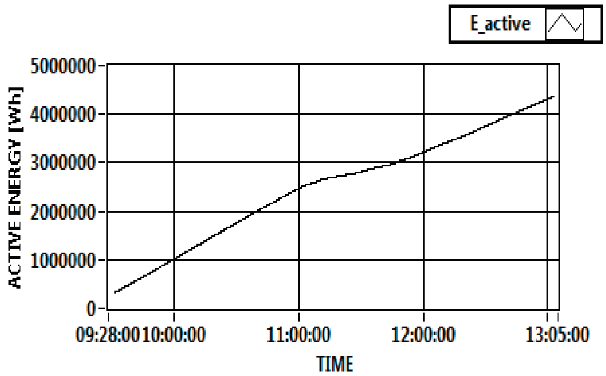

Fig. 19. Time evolution of active energy.

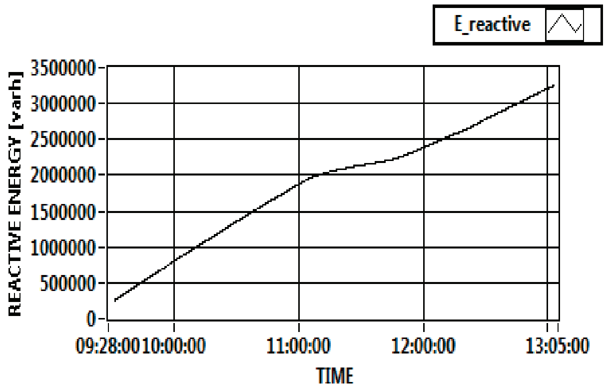

Fig. 20. Time evolution of reactive energy.

TABLE II. THE HARMONIC DISTORTION CONDITION IS PRESENTED IN THE TABLE BELOW:

Circuit	General Power Distributor 20 kV
Total harmonic current distorsion factor -THD_I (%)	4,30
Total harmonic voltage distorsion factor -THD_U (%)	1,37
Individual current harmonics (%)	5– 2,32% 7– 2,04%
Individual voltage harmonics (%)	5– 1,33% 7– 0,50%

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

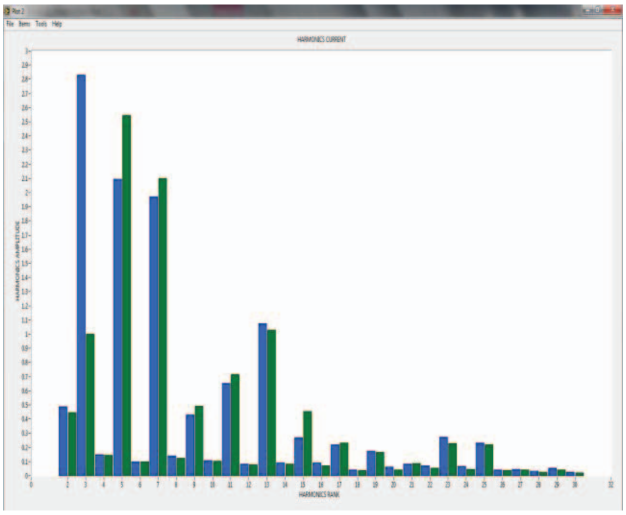

Fig. 21. Individual current harmonics.

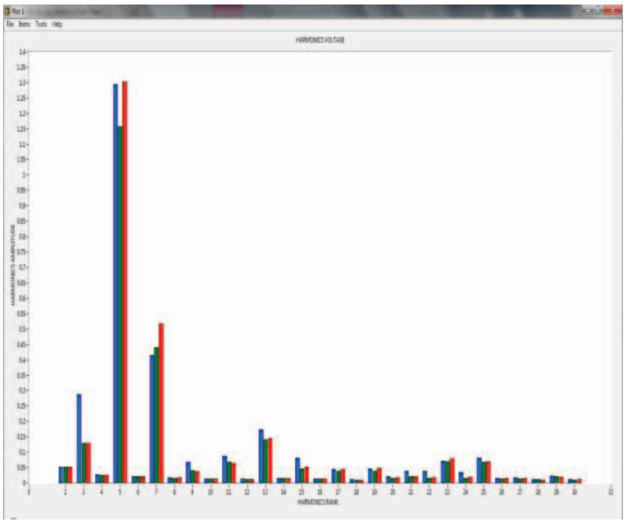

Fig. 22. Individual voltage harmonics.

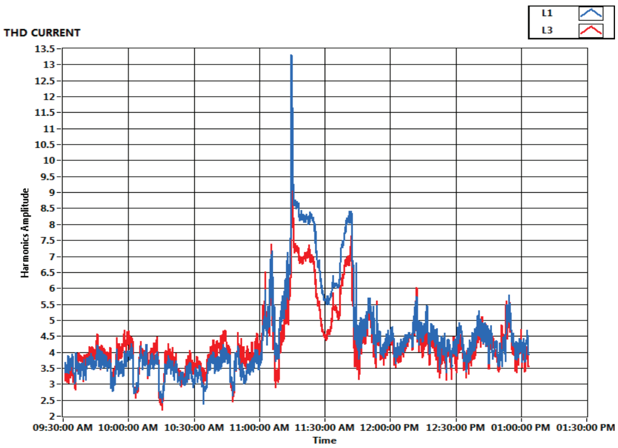

Fig. 23. Total harmonic current distorsion factor -THD_I.

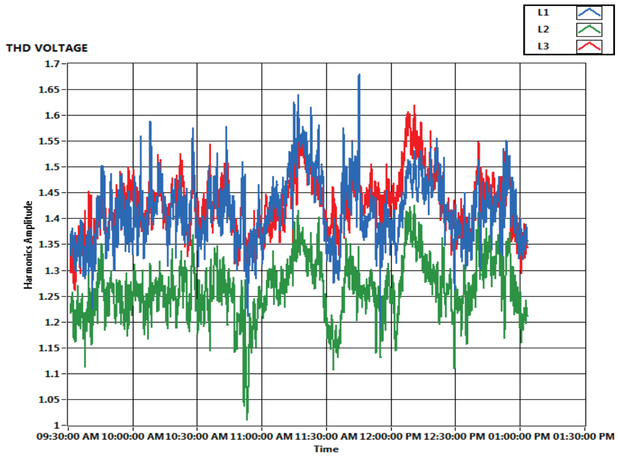

Fig. 24. Total harmonic voltage distorsion factor -THD_U.

From the data analysis we can conclude the following:

- in power factor metering point average is 0.81 (see table 1), situated below the neutral value (0.92);
- the total harmonic current distortion factor (THD_I) in the 20 kV power supply point has a high average value of 4,30% (see table 2 and Fig. 21) and does not exceed the 15% required by the IEEE 519/2014-[16] for ratio I_{SC}/I_{load}=100÷1000;
- the total harmonic voltage distortion factor (THD_U), in the 20 kV power supply point has a high average value of 1,37% (see table 2 and Fig. 22) and does not exceed the 8% required by the IEEE 519/2014-[16].
- in the Fig. 21 may observe that harmonic 5 (2,32%) and harmonic 7 (2,04%) had the highest values of the current harmonics;
- in the Fig. 22 may observe that harmonic 5 (1,33%) and harmonic 7 (0,50%) had the highest values of voltage harmonics.

V. Conclusions

The ability to analyze, 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.

The software developed in LabVIEW allows reading of measured data analyzer, processing data to create a clear picture about the quality of electric energy in an industrial consumer, full power quality analysis can be done at the user's premises [19], [20].

The data processing was achieved using LabVIEW software in terms of the two types of quality indicators. Based on the data obtained from the measurements and using the inter-face 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.

Developing the interface in LabVIEW facilitates the analysis of power quality at industrial consumer level. This can also be applied to other types of consumers.

Received on July 19, 2016
Editorial Approval on November 14, 2016

REFERENCES

[1] F. Vatra, P. Postolache, and A. Poida, “Power quality - Manual for Professionals” , vol.1, ed.itura SIER, Bucuresti, March 2013.

[2] I. Drovtar, J. Niitsoo, A. Rosin, J. Kilter and I. Palu, "Electricity consumption analysis and power quality monitoring in commercial buildings", Electric Power Quality and Supply Reliability Conference (PQ), Tartu, pp.1-6, June 2012.

[3] C. Stanescu, F. Vatra, and A. Poida, "Power quality in romanian electricity market", Electrical Power Quality and Utilisation (EPQU)- 9th International Conference on, Barcelona, pp.1-4, October 2007.

[4] J. Desmet, and A. Baggini, “Harmonics - Neutral Sizing in Harmonic heavily polluted installations”, Copper Development Association, June 2003.

[5] D. Chapman, “Harmonics - Causes and effects”, Copper Development Association, March 2001

[6] J. Desmet, and A. Baggini, "Harmonics - Neutral Sizing in Harmonic heavily polluted installations", Copper Development Association, June 2003.

[7] K. L. Koo, "Power Quality Monitoring in U.K. National Grid electricity transmission system", Universities Power Engineering Conference (UPEC)- 45th International, Cardiff, Wales ,pp.1-6, September 2010.

[8] *Voltage Characteristics of Public Distribution Systems*, Standard EN 50160, 2010

[9] *Law 121/2014 on energy efficiency*

[10] LabVIEWTM Basics I Course Manual, March 1998 Edition.

[11] J. A. Baesso Grimoni, and O. S. Nakao, " Using LabVIEW in a Mini Power System Model Allowing Remote Accessand New Implementations", in Proc. of International Conference on Engineering Education – ICEE, Coimbra, Portugal, , pp.1-5, Septmber 2007.

[12] S. Dang, R. Kakimzhanov, M. Zhang, and A. Gholamzadeh, "Smart grid-oriented graphical user interface design and data processing algorithm proposal based on LabVIEW", Environment and Electrical Engineering (EEEIC)-14th International Conference on, Krakow,pp. 323 - 327, May 2014.

[13] A. Baloi, F. Molnar-Matei, A. Pana, F. Baloi, and F. Dilertea, "LabVIEW implementation for three-phase voltage dip classification", Electric Power Engineering (EPE)- 16th International Scientific Conference on, Kouty nad Desnou, pp.116-121. May 2015.

[14] D.L. Brooks, R.C. Dugan, and A. Sundaram, "Using simulations to enhance PQ monitoring [of industrial power systems]", Power Engineering Society Summer Meeting, Edmonton, Alta., vol.1, pp. 476 - 480, July 1999.

[15] *User Guide CA 8352 power analyzer*, Chauvin Arnoux, France.

[16] *IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems*, IEEE STANDARD 519, 2014.

[17] H. P. Halvorsen. (2014, Mar. 07). Introduction to LabVIEW. [Online]. Available: http://home.hit.no/~hansha/documents/labview/training/Introduction%20to%20LabVIEW/Introduction%20to%20LabVIEW.pdf

[18] LabVIEW MathScript RT Module [Online]. Available: http://www.ni.com/LabVIEW/mathscript/

[19] R.K. Tripathi, and C.P. Singh, "Power quality control of unregulated non-linear loads", Power, Control and Embedded Systems (ICPCES)-International Conference on, Allahabad, pp. 1-6, December 2010.

[20] S. Nuccio, "A digital instrument for measurement of voltage flicker", Instrumentation and Measurement Technology Conference, 1997. IMTC/97. Proceedings. Sensing, Processing, Networking, Ottawa, Ont., pp. 281 - 284, May 1997.