Low Power Embedded System Approach for Power Quality Control

Gheorghe Marc, *PhD lecturer, "1 Decembrie 1918" University of Alba Iulia, Romania*
Mircea Risteiu, *PhD Associate Professor, "1 Decembrie 1918" University of Alba Iulia, Romania*
Ioan Ileana, *PhD Professor, "1 Decembrie 1918" University of Alba Iulia, Romania*

***ABSTRACT* -** This paper starts from a typical energy monitoring situation- a huge number of data, which have to be analyzed, clustered, labeled, and then diagnosed for efficient energy management. This part of the work has been done by using graphical programming –based application, together with a classic USB data acquisition board, and a powerful PC. The monitoring and processing program is designed in a very practical demanded way. With encouraging results, in order to efficient the monitoring application, we uploaded the entire application with specific processing functions into an FPGA embedded system for data preprocessing. The positive results allowed detecting two major abnormal working causes- attrition of the equipment systems, and improper operation of electric power networks. Based on its resources, the embedded system is able to have some control functions, by using a fast digital IN/OUT board together with a GPS module.

***KEYWORDS*—**power quality; LabVIEW programming; embedded systems, FPGA, event detection, monitoring, control.

1. Introduction

concern of traders, because of:

- Limiting the minimum possible reactive power in order to avoid additional costs of electricity;
- Using of equipment supplied at optimal parameters and increased yields;
- The existence of modern equipment performance in technological installations, but the equipment is more sensitive to power quality parameters;
- Management of equipment and technological lines based on process computers, which are composed of microcontrollers, data acquisition and control systems, but whose performance characteristics are affected by disturbances occurred in the supply network.
- Management of equipment and technological lines based on process computers, which are composed of microcontrollers, data acquisition and control systems, but whose performance characteristics are affected by disturbances occurred in the supply network.

Power quality has two distinct aspects to be considered together to ensure safe and efficient working of technological equipment:

- Power quality technical parameters i.e. amplitude, frequency, harmonic content, the symmetry of three-phase systems;

the achievement of a neutral power factor (FPN = 0.92) to be exempted from reactive power. This requires measurements of energy parameters and highlighting nonconformities in order to establish the most appropriate solutions for their compensation.

Power quality to consumers is a primary and permanent

- Quality of service, namely continuity and security of supply.

Here are some of the most common disturbances manifested in power supply networks of machinery and industrial equipment, which are generally generated by consumers themselves:

- Power failure, largely due to not functioning or non-selective protections;
- Voltage variations due to high loads switching;
- Harmonics generated mainly by consumers with non-linear loads such frequency and voltage converters, SMPS, etc.
- Unbalance, resulting from unbalanced power loads, especially among single-phase load voltage three-phase network.

2. Case Study. Customer Requirements

In this paper we present comparative measurements on power supply of compressed air production plants equipped with five compressors of 132kW installed capacity and a cascade control system operation according to consumption.

For a consumer it is important to know the source of these disturbances in order to take measures accordingly, especially for

For measurements we used a data logger Fluke 1735 device and a NI LabVIEW graphical programming environment data acquisition board.

These measurements have emerged as a result of disconnecting the power supply to the compressor station, which had as a consequence, the stop working of the pneumatic equipment, specially the stop working of the special presses of various sizes used in the process.

The unscheduled stopping of these machines lead up to laborious operations to restart the process flow and to significant loss of production and storing a large number of rejects.

In Fig. 1 and Fig. 2 there are presented the graphical representations of the measurements made during one week.

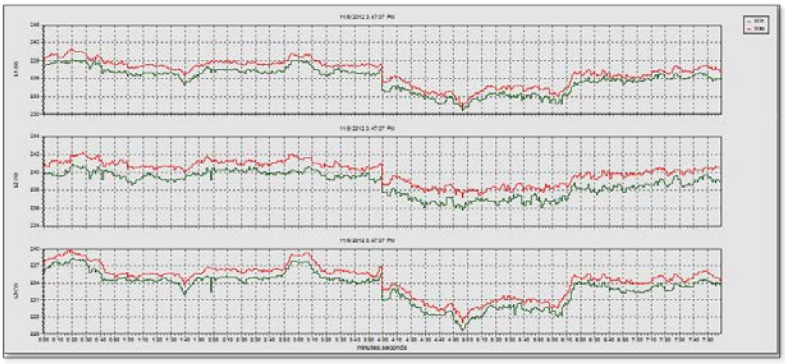

Fig. 1. Time representation of measurements made during one week

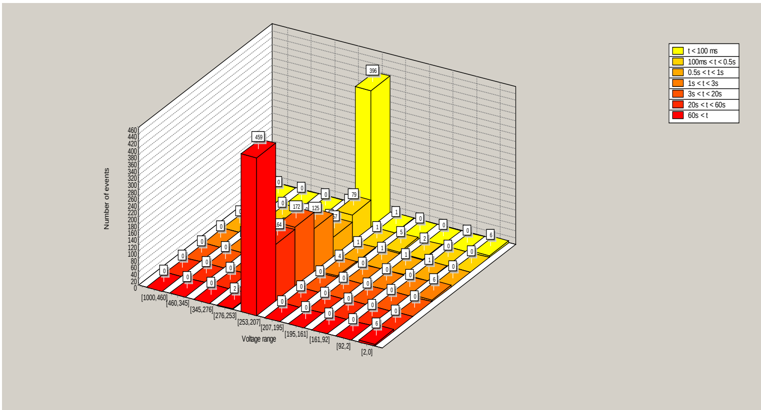

Fig. 2. Graphical representations of the measurements

On a short view of the measurements evolution in figure 1, we see that the measurements run almost similar on the three phase (common representation effective values of the voltages, and currents on the three phases), except some cases where one current and corresponding voltage evolution go different than the other- case that might tell something about the load behavior if some additional data would be recorded. In this state, by local measurements did not catch some events data.

According to regulation, it was necessary to use an event recorder. The events captured like in figure 2 where suggestive but we couldn't diagnose the cases, because some additional information was required.

In both cases, a common conclusion has been raised- some other data should be monitored in order to understand the evolution of the electrical events, some synchronous data should be recorded.

3. LABVIEW MODULAR PROGRAMMING

For the measurement implementation a data acquisition board with 8 inputs has been necessary, with a sampling frequency minimum 100 kHz, software controlled, some specific processing functions, like FFT, some event triggering facilities, and high capacity memorizing have been demanded.

Current measurements were done using a data acquisition board and LabVIEW development environment. During the measurements, we recorded the load currents values during a week in normal production in order to observe their evolution.

The measurement system architecture is shown in Fig. 3.

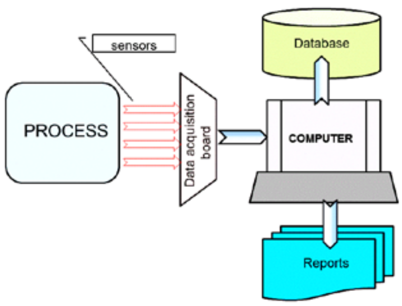

Fig. 3. Data acquisition architecture

Data collection was designed in LabVIEW data acquisition program where we set a minimum threshold current value from which we started to record data. We also set the acquisition time to 40 μs, so we recorded in a second 25.000 of data, following a larger accuracy of records. Because of extremely amount of data, most of consumer monitoring parts have been set to wait, until the evolution of the current in principal monitored consumer was rising. When this current was in increasing tendency, all other monitoring parts where activated for data recording. The recorded data where stored in standard file format (CSV) for later processing.

The programming philosophy was to design in the first stage two different modules: one for data acquisition, and one for data processing. The reason was the main question related to how much data and how many events should be catch in order to understand consumer's behavior. Later, we will see that in four seconds, more than 100000 data must be recorded. Now depending by the hardware resources and optimizing possibilities, we could think to organize the modules and sub VI-s of the same program.

In Fig. 4 and 5 there are presented the front panel and block diagram for the acquisition program.

The parameter values can be viewed in real time and at the same time and they are stored in CSV files and named for easy identification. Using a program designed in LabVIEW data is processed and events that do not fit into normal operation are highlighted.

In Fig. 6 and Fig. 7 are shown the block diagram and the front panel for data processing software module. The program open CVS specific files, overlays data timed synchronized and evaluates data and extracts only windowed data which exceeds normal ranges, for upper level processing.

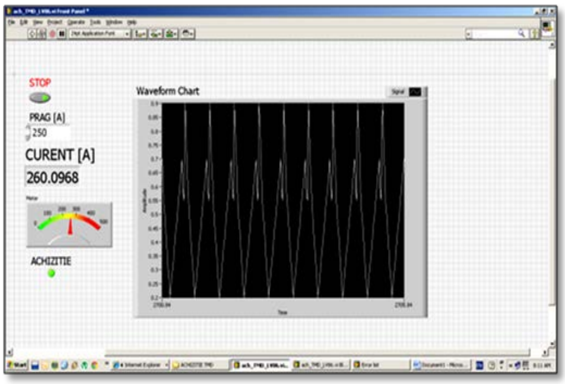

Fig. 4. Front panel

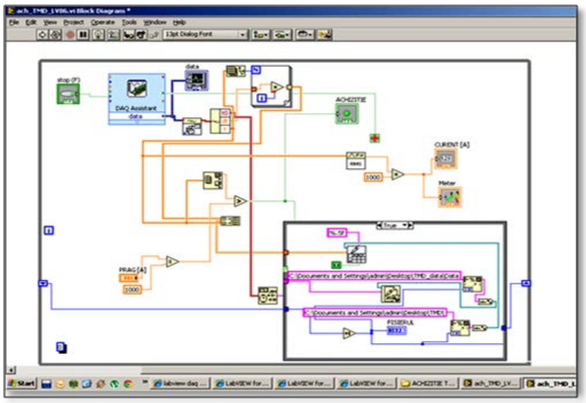

Fig. 5. Block diagram for the acquisition program

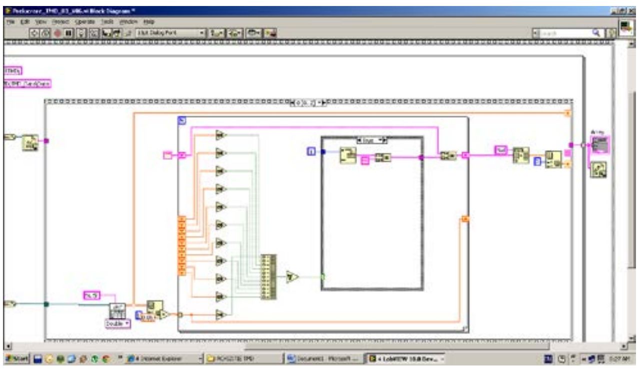

Fig. 6. The block diagram for software acquisition

4. GENERAL CONSIDERATION OF EMBEDDED DESIGNING

A. Centralized versus decentralized measurements considerations in designing embedded

In power quality measurements, centralized versus decentralized refers to where the data is gathered for father processing. In centralized measurements, the clients simply forward all of the data to a central location, and some entity at the central location is responsible for correlating the data with events happened. In decentralized, the clients take full responsibility for processing. "In this case, every sensor or platform can be viewed as an intelligent asset having some degree of autonomy in decision-making." [1] Multiple combinations of centralized and decentralized systems exist.

In order to ensure this combination, there are several categories or levels of sensor monitoring, and decisions making that are commonly used: data alignment, entity assessment, process refinement, tracking and event detection/recognition/identification.

B. Designing embedded systems for power measurements

Andrzej Michalski, in his paper “Quality Engineering Tools used to Design & Optimize a Mobile Measurement Station” [2] presents the main features of the house of quality. For the present paper, the relationships between the technical parameters, and correlation matrix between technical parameters and customer requirements, have the highest intensity of importance.

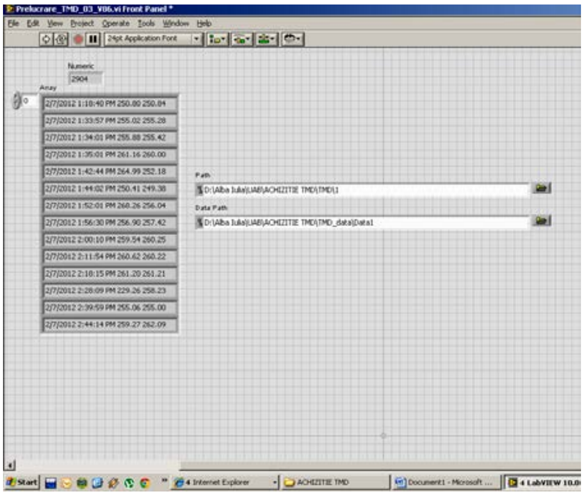

Fig. 7. The front panel for software acquisition

Form this point of view, the general block structure of any measuring system, based on functions, consists in:

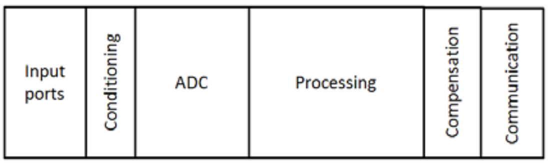

Fig. 9. Block structure of measuring system

When fast data processing is demanded, this typical function- based structure might be analyzed through embedding theory [3] by pipelining: Increasing Instruction Throughput. The main reasons for embedded systems in measurements: processing, self-compensation, reconfigurable measurement systems.

In power quality measurements, in the frame of system reliability ensuring, most of authors [4] recommends, based on the functions structure to identify the structure of the house of quality. For the energetic parameters, we are focused most on self-compensation actions: gain error, non-linear transfer curve, offset error, hysteresis error, and gain variation with temperature / time.

A pipelined microcontroller-based architecture is shown next:

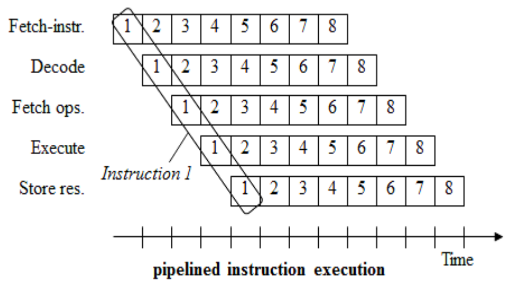

Fig. 10. Pipelined microcontroller-based architecture

In order to design such system, some hardware consideration must be taken into account. The development possibility is only limited by the hardware/software interfacing. A simple system around microcontroller accepts very easy a hardware interface that run faster, and in embedded implementations. Prototyping is an important phase. By using microcontrollers, the project is done faster, with few thirty parts. When we are using microprocessors, if they are not available system-on-chip, or package-on-package, we need special tools for development, and many external resources (especially for communication), by we have the opportunity to use external frameworks that make the project to work in cross-platform implementations.

Based on these considerations, [5] figure the applications versus calculation power. In [6] there are presented some technical solutions for such implementation, and in [7] there is an example of an optimized program flow for an industrial process by using embedded approach.

In our application, some considerations should be underlined here: we need real time response and dynamic power. For these reasons, hundreds of megahertz processor frequency is needed, with a medium side bus. This bus is required because of modular execution and large amount of data manipulation.

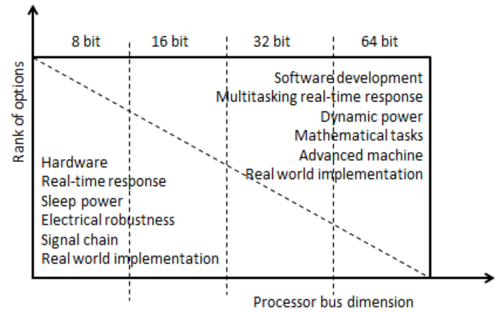

Fig. 11. Program flow for an industrial process by using embedded approach

C. Integrating cRIO embedded device in monitoring and control

For measurement tests, we have used cRIO 9004 [8] with 2 interfaces NI9225 (3-Channel, 300 V rms , 24-bit, Simultaneous, Channel-to-Channel Isolated Analog Input Module), and NI9467 (C Series GPS Synchronization Module). For the test purpose, the measurement structure is shown in next figure:

Fig.12. The measurement structure

where, cRIO internal structure [8] is:

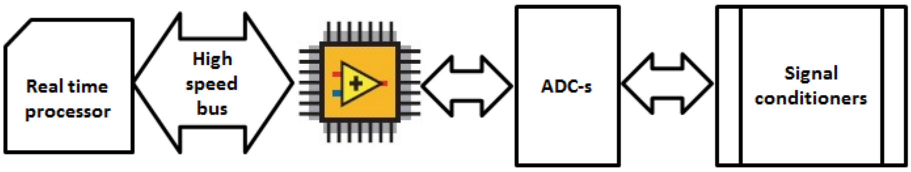

Fig.13. The cRIO internal structure

5. Embedding the Application

Moving process of the LabVIEW application into cRIO FPGA is a simple process in Measurement and Automation Explorer (NI MAX) through we are detecting, configure and upload the application program in FPGA.

In this figure they are specified both phases-application uploading, and running process. The database symbol is an expression of large data capacity of application storing and processing.

For long time measurements NI9225 hardware module has been used for synchronous data acquisition, NI9467 has been used for accurate time synchronization of the events, a connection to a local server database has been used.

6. Conclusions and Future Works

In the monitoring period there were recorded a total of 2904 files, in over 72.5 million data was processed and the events outside prescribed parameters were extracted, leading to defining large number of classes of abnormal events.

During of events analysis two major causes have been localized: attrition of the equipment systems, and improper operation of electric power networks. Figure 15 presents the variation of current drawn by the motor for a period of monitoring, affected by overlap in the technological flow of compressed air consuming equipment.

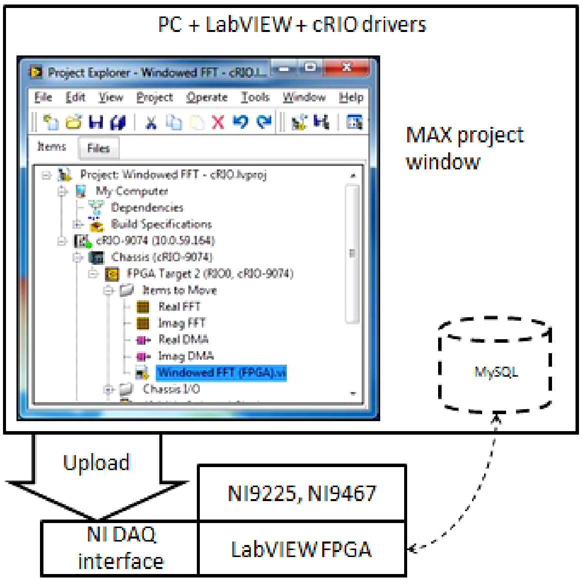

Fig. 14. Application uploading and running

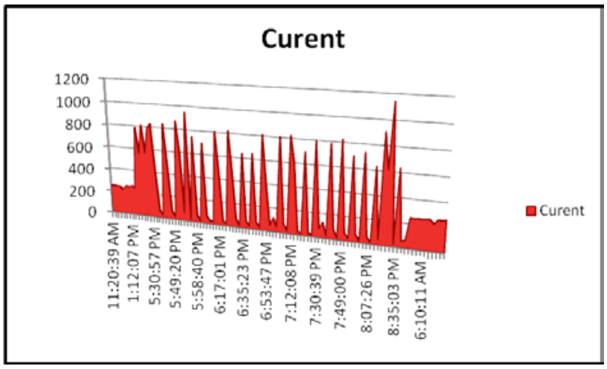

Fig. 15. Variation of current

Although these machines are not part of the production process, they are used as actuators of related installations, respectively vibrators for shaking bags from extraction plant nuisances. Their technological flow overlapping over periods of maximum consumption leads to an overload station compressed air supply to the decommissioning of power plants due to protections. The proposed monitoring system of such phenomena will optimize air consumption respectively will optimize installations working by automating starting operation of compressors by compressed air requirements and associated plants starting in times of low technology consumption.

Another advantage of using this method of power quality monitoring is that the program can simultaneously monitor multiple devices and determine by comparison of operating parameters, which is particularly beneficial in assessing the wear of machinery and yields that works with.

Because of its performances, the proposed embedded system will be used as event detection, for control sequence together with NI9401.

The desktop LabVIEW application or a web-based application will be a master monitor of the embedded monitoring and control system.

REFERENCES

[1] **Garry A. Einicke**, *Smoothing, Filtering and Prediction - Estimating The Past, Present and Future* ISBN 978-953-307-752-9, InTech, February 24, 2012 under CC BY 3.0 license, DOI: 10.5772/2706

[2] **Andrzej Michalski, Bogdan Dziadak**, *Quality Engineering Tools used to Design & Optimize a Mobile Measurement Station*, February 2010 IEEE Instrumentation & Measurement Magazine, Quality Engineering Tools used to Design & Optimize a Mobile Measurement Station, 1094-6969/09, ©2009IEEE

[3] **Vahid/Givargis**, *Embedded Systems Design: A Unified Hardware/Software Introduction*, (c) 2000

[4] *Embedded Design Handbook* July 2011 Altera Corporation

[5] **J.M. Hughes**, *Real World Instrumentation with Python, O'Reilly* 2011 ISBN 978-0-596-80956-0.

[6] **Andras Iosif, Mircea Risteiu, Bogdan Croitoru, Herbert ten Thij,** *Network-based data acquisition for harsh environments*. Advanced network technics, ISBN 978-973-741-218-8, ISBN 978-973-1890-99-9, 2011

[7] **Gheorghe Marc, Remus Dobra,** *Optimization of Production Flow for Construction Aggregates using Modular Control Systems*, 10th WSEAS International Conference on Energy, Environment, Ecosystems and Sustainable Development (EEESD '14)

[8] ni.com, last visited in 12.01.2014