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Three Phase Power Monitoring using Virtual Techniques

Peter Ivanov Yakimov and Georgi Todorov Nikolov

Abstract - **This paper presents a power monitoring system that allows analyzing all phenomena related to power quality. The objective is to describe some power quality measurements and analyses that are better served by monitoring with multifunctional data acquisition systems rather than dedicated power quality analyzers. Proposed system is flexible and open to changes and improvements. Measurements which are discussed include three phase voltages, currents and their phasors, active, apparent and reactive powers, power factor and frequency.**

Keywords – **Data Acquisition System, LabVIEW, Power Monitoring, Virtual Instrumentation**

I. Introduction

The need to manage power is never more critical than when power prices grow up and power quality becomes suspect. Electrical technicians today are more aware of power consumption and are on the watch for consumption that's higher than anticipated. Power monitoring is needed to analyze the power demand [1]. Furthermore, observing the quality of the power helps to analyze the source of disturbance that may cause important stability problems in power systems, or may seriously affect the operation of devices.

Three-phase power measurement and calculation techniques are well established [2, 3]. However, a number of factors have precipitated the need for flexible and reliable measurement and monitoring systems for use in power system applications. Several power quality monitoring systems are available in commerce but almost all of them have the big disadvantage of being embedded and close because it is very difficult to connect different instruments built by different manufacturers to the same system infrastructure and to merge all the monitoring results for unified analyses. Moreover, the commercial power monitoring systems are made up for the general and standard purpose of analyses so they do not always meet the specific customer demands.

On the other hand National Instrument's LabVIEW data acquisition hardware and software module has become one of the most widely used tools to capture, view, and process controls, instrumentation, and power system data both in academia and the industry [4].

In this paper, a simple and cost-effective measurement tool that is based on LabVIEW is presented. This tool measures three-phase voltages and currents using voltage and current transducers and multifunctional data acquisition system. The software calculates all aspects of power such as active, reactive, apparent power, power factor, and phasors. The monitoring system allows performing not only standard analyses, required by a generic customer but also any advanced or specific analysis aimed to the research or to insight knowledge. The monitoring can be performed over long periods and the results of the analyses can also be post-processed to extract statistical information on the disturbances detected.

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II. Virtual System Design

The proposed virtual system is structured with the following hardware and software blocks: (a) Signal Conditioning, (b) Data Acquisition System (DAQ), (c) DAQmx drivers, (d) Waveform measurement functions, (e) LabVIEW Front panels. The system's block scheme is reported in Fig.1.

The advantage of such digital sampling system is that it is comparatively easy to calibrate, and that digital multiplication is precise and does not cause linearity problems that could occur in power meters based on analogue multiplication. Furthermore, it enables accurate power measurements in non-sinusoidal situations and makes it possible to calculate the power of the different harmonics.

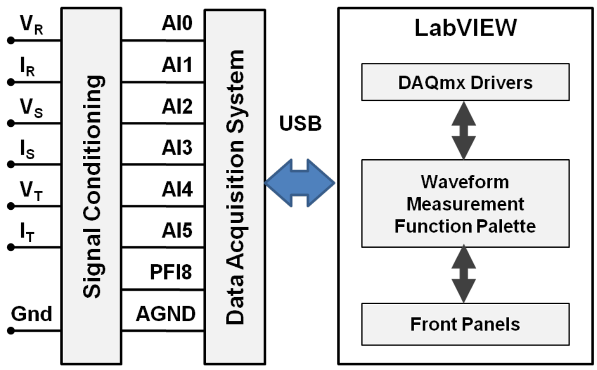

Fig.1 Structural block diagram of the virtual system for power parameters measurement and monitoring.

A. Hardware Design

Signal Conditioning. The purpose of the analog front end is to normalize the signals in order to match the range of the analog-to-digital converter. There are three voltage and three current channels needed for the three phase (R-S-T-N) power measurement. The input ranges depend on the measuring transformers ratios and in this case the maximum values are 70Vrms for the voltage and 7Arms for the current. The range of the analog-to-digital converter is ±10V, so the circuits are designed to normalize the signals according to the ranges. The voltage signals are applied to voltage dividers. The first channel, corresponding to phase R is described on the Fig. 2. There are added protective Zener diodes. The signals are applied to the analog inputs AI0, AI2 and AI4 of the DAQ. For frequency measurement and for synchronization is provided square-wave signal using the comparator DA_2. The pulse signal is applied to the input PFI8 of the DAQ. It is required to be electrically isolated, so the optocoupler OC_1 is added.

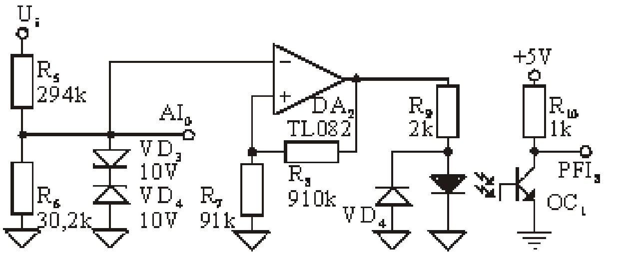

Fig. 2 Signal conditioning circuit for first voltage channel

The input currents are converted to voltage by current transformers, connected to active compensated circuits. The first channel is explained on Fig. 3. The current transformer CT has two equal secondary windings with ratio 1:1000. The purpose of the circuit is to generate the same magnetic flux as the input current does. In this case the voltage over the secondary winding w_2 will be zero and the output current through the secondary winding w_3 will be 1000 times less than the input current. The voltage signal from the resistor R_3 is applied to the input of the DAQ. The three signals are connected to analog inputs AI1, AI3 and AI5 of the DAQ. In this circuit protective Zener diodes are added as well.

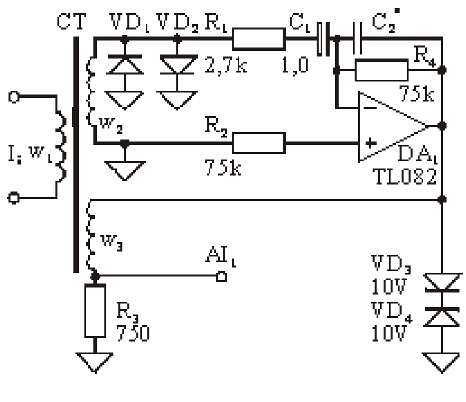

Fig.3 Current transducer for first current channel

Data Acquisition System. The second component of the designed virtual system is a modular DAQ. The multifunctional DAQ boards perform a variety of tasks, including analog measurements and generation, digital measurements, timing I/O and various types of analogue and digital synchronization techniques. For the measuring part of the virtual system reported here, the National Instruments' multifunctional DAQ USB-6251 is used. This device provides connection to sixteen analog input (AI) channels with 16 bit resolution and 1200 kS/s per channel. For frequency measurement two 32-bit counters with 80 MHz sample clock are used. The connection between voltages, currents and DAQ is shown in Fig. 1.

B. Software Design

The Fig. 4 presents the overall graphical code or block diagram of the proposed method for synchronous measuring of three voltages and three current applications. As can be seen on the figure, there are a number of DAQmx functions that controlled measurement [6]. First one is *Create Virtual Channel* The instances of this polymorphic function correspond to the type of the channel, such as analog input, and range of the measured voltage. The second one is *Timing*, that configures the number of samples to acquire and creates a buffer. This function is responsible for exact integer number of periods measurements. Whatever measurement algorithm is used, an exact measurement of the power parameters of a stationary periodic signal requires that the measurement is made over an exact integer number of periods. This can be achieved by synchronizing the measuring circuit to the fundamental frequency of the signal. If the sampling frequency is much higher than the frequency of the signal, the number of samples can be adjusted such that the measurement is synchronized. In presented system the sampling rate is programmed to be 200 kS/s and 8000 finite number of samples are acquired. In such a way exactly two periods of measured signal are taken.

The next important actions that data acquisition board, controlled by DAQmx perform are producing a sample and starting a waveform acquisition. In order to ensure measurement of every voltage and current always to begin from one and the same reference point the digital triggering is used. Usually, digital trigger signals are connected to PFI pins of measurement device. In the presented virtual system for digital trigger the optoisolated signal PFI8 is used (Fig. 2). *Start Digital Edge* function configures the task to start acquiring on a rising edge of a digital signal. To treat all six channels consecutively the *for loop* with six iterations is used that provide all measurement waveform to be acquired at the same conditions.

In the bottom part of the Fig. 4 is shown the software code for frequency measurement. *CI Period* function creates a channel to measure the period of a digital signal. The input for period measurement is the same PFI8, that provides synchronization. The selected measurement method is *High Frequency* with two counters. Measurement accuracy increases with increased measurement time and with increased signal frequency.

The calculation of amplitudes and the phase angles of each voltages and current are made by various build in LabVIEW functions and algorithms which is discrete versions of transforms from time-domain to frequency-domain [5]. The two basic calculation methods that are used in this work to transform the sampled sequences of the signals into values of the desired quantities is the discrete integration and discrete Fourier transform. By means of discrete integration methods accurate values can be obtained of parameters such as root mean square values of voltage and current, apparent power and the phase angle between sinusoidal voltages and currents.

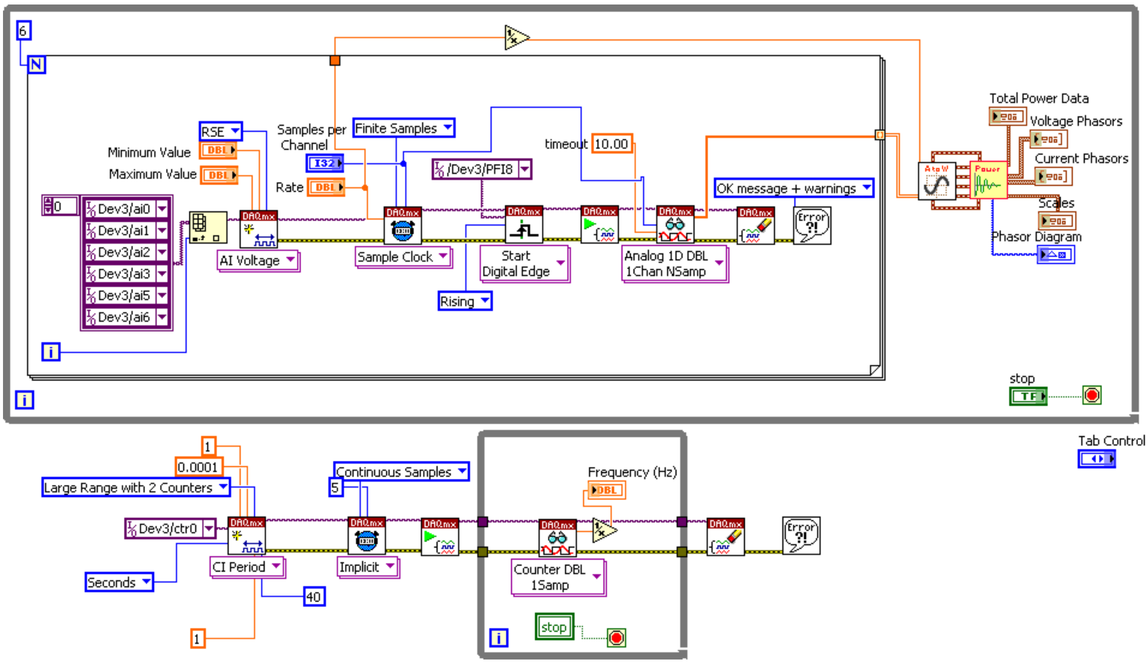

Fig. 4. Block diagram of software developed for measurement and synchronization.

Analysis functions for all of the fundamental power calculations discussed in this paper can be found in the Electrical Power Measurements (EPM) Palette for LabVIEW that is available online. These common functions include:

- Voltage and Current Phasor Calculation (RMS value pared with phase angle);
- Real Power (Watts);
- Apparent Power (VA);
- Reactive Power (VAR);
- Power Factor and
- Phasor Diagram.

In Fig. 5 is shown part of block diagram in which implementation of these functions can be seen. These functions are polymorphic and in this case the three phase application is selected.

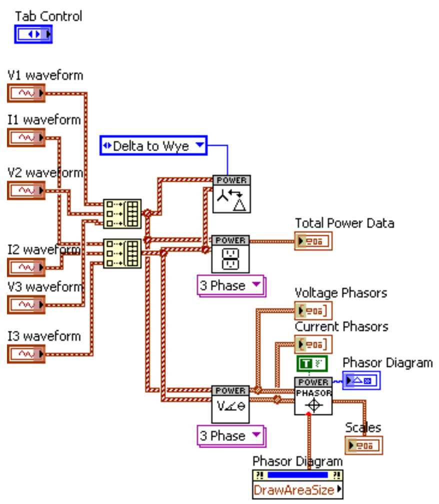

Fig. 5 Block diagram of software for power calculation

To certify the measurements, it has been necessary to calibrate the signal conditioning circuit. The most practical method is to calibrate each transducer in one position only. The calibration procedure yields the use of a calibrated current and voltage directly connected to the virtual system. These voltages and currents are generated by electronic load and measured with 5 ½ digits multimeter HP 3478A. Calibrating coefficient for each voltage and current channel is calculated and implemented in software as is shown in Fig. 6.

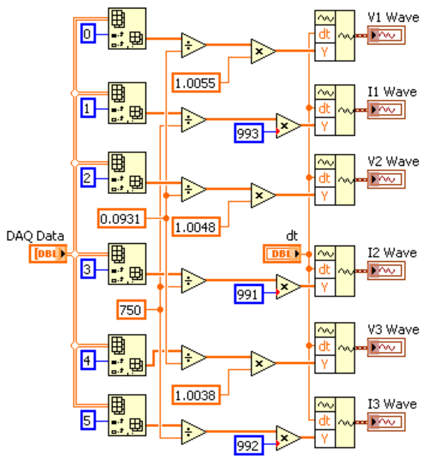

Fig. 6 Implementation of calibrating coefficient

III. Experimental Results

The images in Fig.7 and Fig.8 shows the Front Panel of the developed virtual system for power monitoring. To simplify the user interface and to make it more usable, the Front Panel is organized as a collection of pages grouping various subsections of correlated controls and indicators. The first section is DAQ setup section and is devoted to the basic requirements of running the proposed instrument (setting of DAQ gain, choice of the resolution, define input terminal configuration, sample rates, sample mode, sample per channel and so on). This section is designed to be not visible for an ordinary users. The second section (Fig.7) is the page of results where the proposed quality indices are displayed. In the left part RMS values and phasors of voltages and current are placed. Active, Apparent and Reactive Power are indicated in the right part of the page in conjunction with calculated Power Factor and measured Frequency.

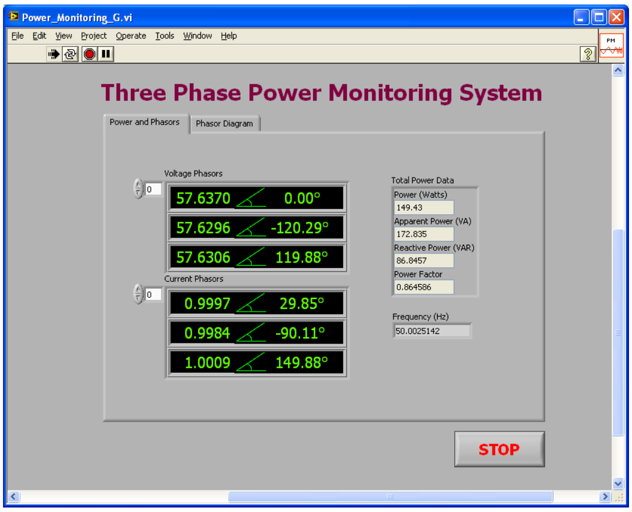

Fig. 7.The base Front Panel of the virtual system

The third section is devoted to illustrate Phasor Diagram and can be seen in the Fig. 8. This graphical interpretation lets easy test for interaction between phases or between voltage and current. In the right part of the figure the scales of the voltage and current is positioned. For sake of brevity, the description of the other sections, useful to a characterization of power systems are omitted.

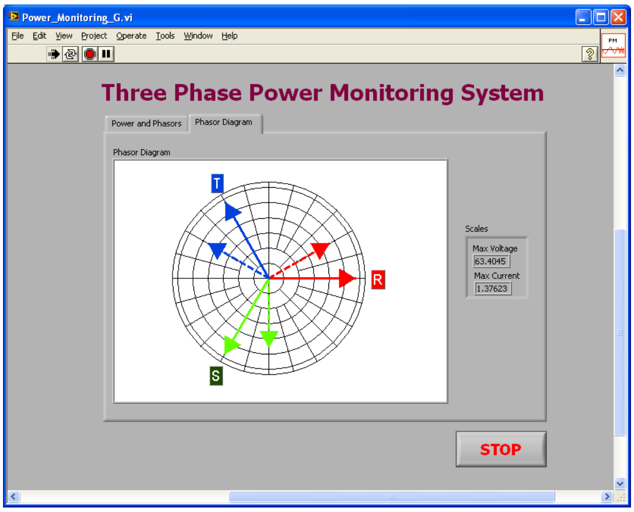

Fig. 8.Front panel of Phasor diagram

IV. Conclusion

A data acquisition USB Device has been designed, developed, realized and characterized to be used in power quality monitoring activities. The system simultaneously manage six data acquisition channels to allow acquisition on three phases plus neutral lines working at 4000 samples per 50 Hz period. This virtual power quality monitoring system allows analyzing almost all phenomena related to power quality. The monitoring system has been presented with reference to its modular architecture describing the several measurement substations that are based both on commercial and advanced high performance devices. The system is flexible and open to changes and improvements. The USB serial communication makes data acquisition software portable over many platforms, regardless development environment and programming language.

The realized USB Data Acquisition Device reduced the total costs of entire system and it has been proved to be competitive with actual data acquisition boards in terms of costs and performances. Finally it was implemented a calibration process to characterize the system and prove the matching performances with test data.

The developed data acquisition system is being used extensively to provide the students a hands-on laboratory experience related to electrical, electronics, and instrumentation.

Acknowledgement

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