# Using LabVIEW in a Mini Power System Model Allowing Remote Access and New Implementations

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*Abstract* - **The paper presents the development of an experiment in an electrical power systems laboratory using Hall tension and current sensors, an A/D board and the LabVIEW software (National Instruments) to monitor electrical variables, and to calculate and analyze the power, energy and power factor of a mini power system in low tension. The minisystem contains synchronous generators of 2kVA-220 V, a transmission line model with reactors and capacitors, and a resistor box to represent a passive charge or an induction motor. The A/D board allows the control of digital outputs, which in turn, can control contactors that switch on or off elements of the circuit under analysis. A program was developed in four main screens: the first screen enables the monitoring of and intervention in the experimental assembly; the second shows the waveform of the signals monitored in the minisystem with their respective harmonics; the third screen shows the phasor graphs of all current and tension signals simultaneously; the fourth and last screen provides a virtual synchronoscope, allowing the analysis of tension and frequency adjustments in the parallelism operation of the minisystem with the local power company. The program allows remote access to the experimental assembly of the mini power system from the computers installed on each laboratory bench. With the experiment, the concepts studied in theory are consolidated. A set of new and future implementations are presented too.**

*Keywords- LabVIEW, Data Acquisition, Signal Processing, Power Systems, Remote Access*

## INTRODUCTION

The benefits arising from the usage of data acquisition and treatment systems by means of suitable hardware and software have consolidated their use as tools. Systems in the electrical power area are frequent users of these tools to make the operation and maintenance easier. Therefore, in the teaching and learning processes in undergraduate laboratories of electrical engineering courses, students should become familiarized with these systems.

The aim of the paper is to present some potential applications of the LabVIEW software which, in association with data acquisition hardware, is applied in experiments with electrical power. By means of a set of electrical parameters acquired through a group of sensors, a data conditioning board, an analogue/digital conversion board and a standard PC microcomputer, the software allows several treatments of these data, their visualization and also the recording of these data in files for later analysis. The software is easy to program, as it is visual and has an interface that allows the visualization of how the data propagate during the process of signal acquisition and treatment. The sensors that measure current or tension signals are of the Hall-effect type, which in itself assures galvanic insulation of the signals. There is a board that conditions the signals for the analogue/digital conversion board from National Instruments, which has 16 analogue inputs converting analogue signals in the range between 0 and 10 V to digital values.

A program was developed using the software LabVIEW 7.1 Professional, from National Instruments (2003), for the acquisition and treatment of the electrical signals of a mini electrical power system. The program allows the user to monitor and interfere in the experimental assembly, to analyze the waveform of the signals and their respective harmonics, and to visualize the phasor graph of all current and tension signals simultaneously. It also allows the visualization on the screen of a virtual synchronoscope, enabling the verification of tension and frequency adjustments necessary in the parallelism operation of the minisystem with the local power company.

This program associates the Internet technology with the acquisition and analysis tools used in the laboratory to allow the student to have remote access to a single experimental assembly of the mini power system via the computers installed on each laboratory workbench. The paper describes the architecture and the software developed and the remote access functionality and finally new implementations in course.

## BASIC SYSTEM ARCHITECTURE

Figure 1 shows the basic architecture of the system developed for the acquisition and treatment of signals.

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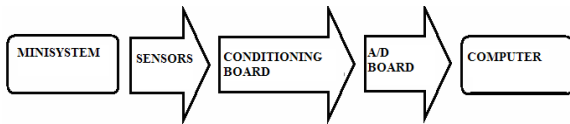[2] Osvaldo Shigueru Nakao,  USP, losvaldo.nakao@poli.usp.br

FIG 1 – BASIC ARCHITECTURE OF THE SYSTEM DEVELOPED FOR THE ACQUISITION AND TREATMENT OF SIGNALS

In the minisystem, the power source is composed by a continuous current machine simulating the turbine, which, connected to the axis of a synchronous generator of 2kVA-220 V, simulates the power plant. The transmission line model is obtained through the association of reactors and capacitors following the pi model. There are two possibilities for the charge: a resistor box representing a passive charge or the power company itself by means of a parallelism operation.

The sensors employed are based on Hall-effect transducers and thus have a rapid response to variations in tension and current. They may be configured according to appropriate reading ranges: up to 180 V or 270 V for tension sensors and up to 5, 6, 8, 12 or 25 A for current sensors. These configurations are informed to the program so that the correct tension and current values can be obtained.

The conditioning board feeds the transducers, conditions the electrical signals of the transducers into tension signals with maximum amplitude of 10 V, and also connects relays to the digital outputs of the A/D board.

The A/D board used is the PCI 6023E, from National Instruments, with 16 analogue inputs of 12 bits (11 of amplitude + 1 of signal), sampling frequency of 200 Ksamples/s and insulation for up to 45 V. The tension range is adjustable and should also be informed to the program.

Figure 2 shows a photograph of the complete system, with sensors, the signal conditioning board and the microcomputer with an analogue/digital conversion board.

The minisystem may also use charges simulated by resistors-inductors-capacitors, induction motors, light bulbs and compositions of rectifiers and inverters with DC motors and induction motors.
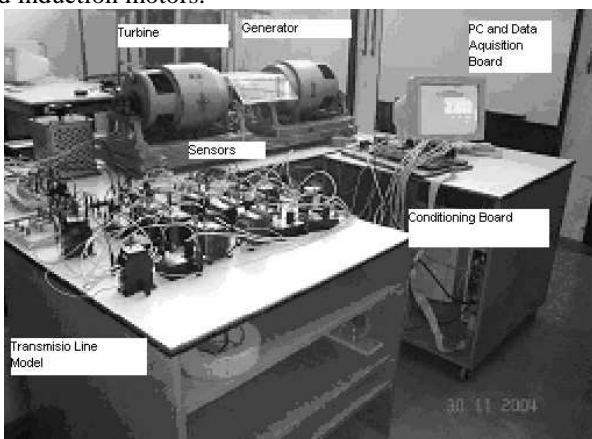


FIG 2 – PHOTOGRAPH OF THE MINISYSTEM, WITH SENSORS, CONDITIONING BOARD AND PC WITH A/D BOARD

With the combination of these various elements it is possible to simulate a great number of experimental assemblies to explore and reinforce theoretical concepts.

The transmission line model represents a real transmission line with the following parameters:
Voltage : 440 kV
lenght: 400 km
positive sequence resistence: 0.02 $\Omega$ /km
positive sequence reatance : 0.3 $\Omega$/km
positive sequence capacitance : 13.4 nF/km
zero sequence resistence : 0.28 $\Omega$/km
zero sequence reatance : 1.2 $\Omega$/km
zero sequence capacitance : 8 nF/km

The scale factors between the real transmission line parameters (voltage, current, power and impedance) and the model are showed in table 1. Figure 3 shows the transmission line model used to define and build the coils and the capacitors.

Table 1
SCALE FACTORS TRASMISSION LINE PARAMETER

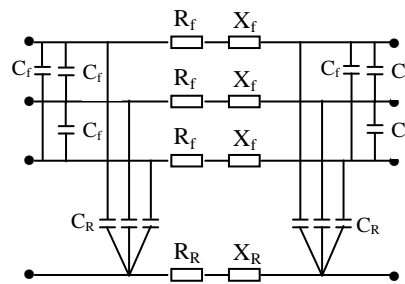| Scale Factors | | | |
|---|---|---|---|
| Parameter | Simbol | Definition | Value |
| Voltage | $k_v$ | $V_{real}(kV)=k_v$ $V_{modelo}(kV)$ | 2.0 (kV/V) |
| Current | $k_I$ | $I_{real}(A)=k_I$ $I_{modelo}(A)$ | 200 (A/A) |
| Power | $K_s$ | $S_{real}(MVA)=k_s$ $S_{modelo}(VA)$ | 0.4 (MVA/VA) |
| Impedance | $K_\square$ | $Z_{real}(\Omega)=k_\Omega$ $Z_{modelo}(\Omega)$ | 10 ($\Omega/\Omega$) ) |



FIG 3 – TRANSMISSION LINE MODEL

## PROGRAM DEVELOPED

The developed program adopted the concept of virtual instrumentation, creating modules based on the software LabVIEW 7.1 Professional (known as VI – Virtual Instrument) [1],[2]. In the source code of the program, the signal variation ranges to which the sensors must be adjusted in the assembly were defined, allowing the conversion of the

actual measured signal to the visualized and calculated signal.

For calculations of active and reactive power, power factor and frequency, some VIs were developed according to [3], [4] and [5] in three-phase sinusoidal systems. A VI was also developed for the harmonic analysis of current and tension signals including the concept of the harmonic distortion factor.

In the program developed there is a user interface divided into four screens to display the experimental assembly, the waveform and harmonics, the phasor graph and the virtual synchronoscope.

Figure 4 shows the first screen, which presents the experimental assembly observed in laboratory. It allows the operation of the keys both at the beginning and end of the transmission line model, as well as of the respective reactive compensations. It indicates the present state of the keys through a picture of the experimental assembly. On this screen it is also possible to see the indication of the effective tension values at the beginning and end of the line, the effective currents for the three phases, and the values of active, reactive and apparent power and of frequency.
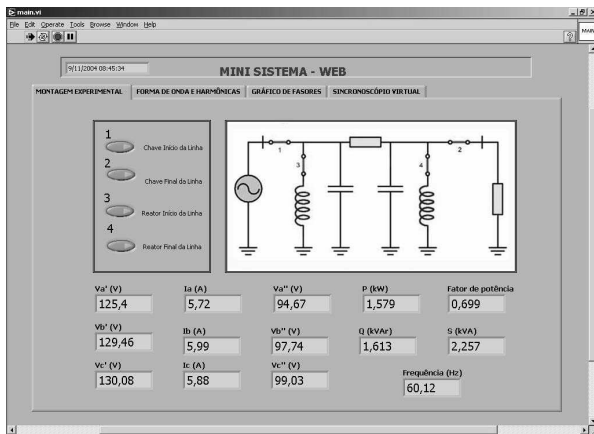


FIG 4 – SCREEN OF THE EXPERIMENTAL ASSEMBLY

On the second screen it is possible to select any tension or current signal monitored in the minisystem and present its waveform with the respective harmonic decomposition through a table. The value of the harmonic distortion factor of the selected signal is also indicated. Figure 5 shows the screen of the waveform and the level of harmonics.

The third screen of the program can be seen in Figure 6, with the indication of the tension and current signals of the minisystem in the form of phasors, all of which being indicated simultaneously in a single graph. On this screen the student can verify the difference of phase angle in relation to the tensions in different situations of charge and operation of the minisystem.

The next screen displays a virtual synchronoscope, allowing the analysis of tension and frequency adjustments for the parallel operation of the minisystem with the local power company. Through the three tension phasors at the output of the transmission line and the three tensions of the power company, it is possible to observe the criteria of same amplitude, sequence of phases and frequency. Figure 7 shows the screen of the virtual synchronoscope.
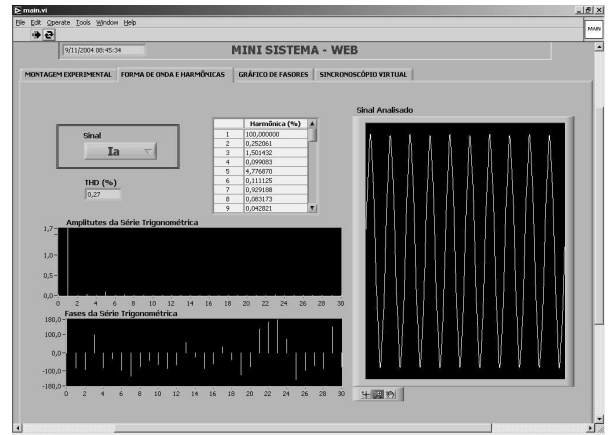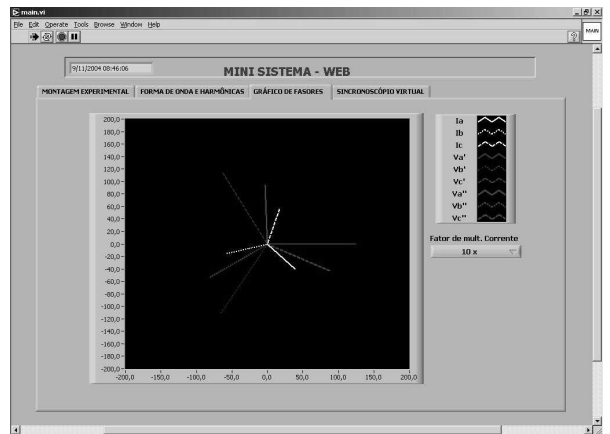


Fig 5 – Screen with waveform and harmonics



FIG 6 – SCREEN WITH PHASOR GRAPH

## REMOTE ACCESS FROM LABORATORY BENCHES

For visualization and control purposes, the program developed to monitor the minisystem from computers connected to the Internet has remote access, allowing several workbenches in a laboratory to share the same experimental assembly.

Students may follow from their benches the demonstrations developed by the professor in the experimental assembly connected to the server computer, which actually controls the minisystem.

In the computer that has the A/D board installed and monitors the whole minisystem, a server is configured using the automatic tool Web Publishing Tool, available in the software LabVIEW 7.1 Professional. Through the intranet of the laboratory the computers on each workbench can, through TCP/IP communication, access and control the minisystem from an Internet navigator (Internet Explorer, for example).
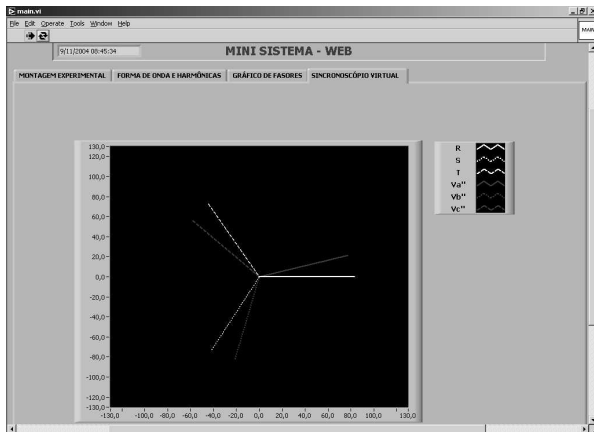
FIG 7 – SCREEN OF VIRTUAL SYNCHRONOSCOPE

From the original program, LabVIEW creates an *.http* file and makes it available through a self-configured internal server in the computer with the A/D board (server computer). When any computer accesses this file in the server computer via Web, the screen of the program being executed in the server computer becomes automatically available in the microcomputers on the benches through the Internet navigator.

## NEW IMPLEMENTATIONS

This implementation allows thinking in another kind of applications of acquisition and treatment of a mini power system data. Actually a final course student are developing an implementation time versus current curves of an over-current relay that could turn-off the circuit using a switch controlled by the signal of trip relay function. Labview allows implementing many kinds of time versus current functions, like the traditional IEC standard curves.

Other kind of relays could be implemented like directional relays, over-voltage relays, impedance relays and differential relays used to protect transformers, generators, motors, buses and lines.

Other kind of application is the study of short circuit analysis using the data measured of many kind of controlled short circuit situations in the mini power system. One phase, two-phases, two-phase to earth and three-phases short circuit using reactors assembly to reduce the current values could be implemented and using the data acquired and treated allows to view the symmetrical components currents and voltages and the phase and line values in numerical and phasorial view.

It is possible to implement an excitation control of the generator field controlling the dc current applied to the field coil and a control of the induction motor speed controlling the inverter that control the voltage to simulate the "turbine" speed control system.

With the use of a non-linear load is possible to see the real propagation of the harmonic current components flowing in the mini system elements, like transformers and transmission lines models. The transformer connections could modify and/or cut some kind of harmonics affecting the composition of them in different voltage level of the circuit. The use of passive and/or active filters in strategic points of the circuit could change the harmonic level propagation in the circuit protecting some kind of elements of the circuit that are sensible to harmonic presence.

## FINAL CONSIDERATIONS

This paper has shown the results of a project in which the software LabVIEW 7.1 Professional was employed to automate acquisition, treatment, visualization and storage of signals from a mini power system. As advantages of using this tool to acquire and treat data, one can mention the possibility to monitor many points simultaneously and to save the data in files for later analysis in LabView itself or in another tool such as MATLAB, MathCad or Mathematica.

The student will be able to focus on gaining a broader view of the process and of the data acquired and treated in the system, thus having more subsidies to analyze the phenomena involved in the experiments.

The association of the Internet technology with the tools creates the means for the development of learning environments in which the students may be involved remotely in conventional laboratory activities as if they were physically present in the laboratory.

Besides the necessary theoretical basis acquired in conventional classes and reading materials, the hands-on experience provided by laboratories are vital elements in the education of an engineering professional [6]. However, configuring and maintaining a laboratory available for long periods has a high cost. With a remote laboratory the use of resources can be optimized, making them available for more than one teaching institution and reaching a greater number of students.

The assembly implemented allows thinking in another kind of new experiences that could be used in the teaching learning process with engineering power energy students about power systems models and components and analysis in normal and in transient situations. Some of the presented ideas of that new possibilities are showed in this paper and some of then are actually in design and implementation state.

### ACKNOWLEDGEMENT

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