

## THREE-PHASE VIRTUAL INSTRUMENT MEASUREMENT SYSTEM

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### Abstract:

Electrical engineering laboratory often involves measurement of current and voltage signals. Conventionally, it is accomplished by using various types of hardwired measurement equipments. If further signal information is required, the oscilloscope becomes the preference. However, for measurement of voltage that is connected to the mains, prior knowledge to isolation is a must. Conventional oscilloscopes neither have the isolation function nor the data logging capabilities for further analysis. This paper presents the hardware and software development of a custom-built three-phase measurement system, equipped with isolation and data logging features. It also includes a description of the application of virtual instrumentation, written in LabVIEW that uses the developed hardware. A case study will also be presented.

### Keywords:

Measurement system, Virtual Instrument, Isolation.

## 1 Introduction

Electrical engineering subjects often require students to conduct practical experiments in the laboratory. The equipment under test, such as the three-phase induction motor, synchronous generator and transformers are connected to the three-phase mains. Obviously, three-phase currents and voltages are the parameters of interest in the experiment. In order to obtain the parameters, one must measure it. Conventionally, the physical parameters are measured using the vendor defined hardwired measurement instrument, such as voltmeters and ammeters. If those signals are to be visualized, the oscilloscope is the preference instrument. Nowadays, technological advancement has made it possible for us to virtually acquire, display and analyze these parameters. The virtual instrument consists of several specialized subunits, i.e. computer, dedicated software and some hardware.

Researchers [1-6] have shown a promising result in the application of virtual instrumentation in their respective laboratory using LabVIEW software. LabVIEW's virtual instrument (VI) consists of a front panel and block diagram. The front panel is a graphical user interface used for data presentation and the control input can be highly customized for a specific application, whereas the block diagram shows the mechanics on what is being actually processed and displayed in the front panel. Moreover, reduced cost and shorter system development time have encouraged interest in the application of virtual instrumentation. Successful industries such as Flextronics and National Semiconductor are using virtual instruments as their product development, testing and inspection platform.

This paper provides a detailed description of the application of virtual instrumentation on three-phase currents and voltages measurement. The major functions of the developed virtual instrument are currents and voltages signal display panel, power meter, power factor meter and frequency meter using Fast Fourier Transform (FFT) computation.

## 2 Virtual Instrument Measurement System Architecture

The proposed VI measurement system is as shown in Figure 1. There are two types on three-phase incoming signals, i.e. voltages and currents. Incoming current signals are fed to the current transducers to convert the information into voltage signals, while incoming voltage signals are stepped down using the voltage divider. There is also a signal conditioner to bring both the signals to a level where it is safe for data acquisition board (DAQ).

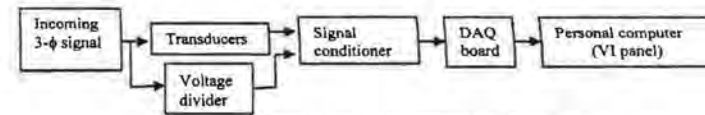


Figure 1. Virtual instrument architecture

The DAQ is a device that acquires output signals in terms of voltage from the signal conditioner. It serves as the communication bridge between the physical incoming signals and the software installed in the personal computer. Then, the LabVIEW code is written to communicate with the input signals via DAQ. Finally, VI of a dedicated application is developed using LabVIEW graphical programming language.

## 3 Hardware development

The endeavor is to build the complete prototype so that the accurate measurement can be made. The three major parts of the hardware are the transducers, signal conditioner and data acquisition board. All these parts need to be identified carefully to achieve optimum result. Besides that, a power supply for the IC used in the prototype was also developed. Figures 2, 3 and 4 show the prototype of the power supply module, current module and voltage module respectively.

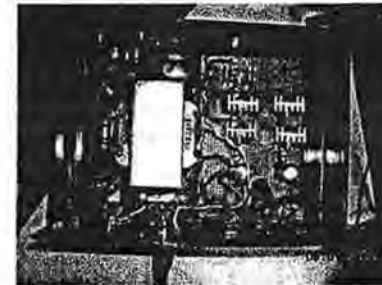


Figure 2. Power supply module



Figure 3. Current module

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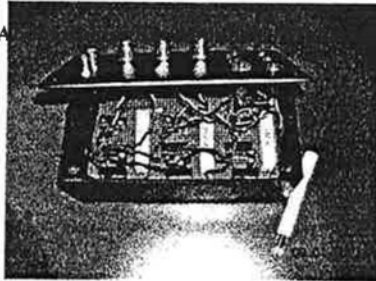


Figure 4. Voltage module

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## 1 Introduction

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## 2 Virtual Instrument Measurement System Architecture

(DAQ).

**3.1 Current Transducers**  
 Incoming 3-φ signal  
 The Hall Effect current transducer LA 100P from LEM was used to convert the current signal into the voltage signal, which provides galvanic isolation between the primary circuit (high power) and the secondary circuit (electronic circuit). It can measure up to 100 ampere with excellent accuracy and good linearity. The output of this transducer is in the range of  $\pm 12V$ ; however, it can be reduced to  $\pm 10V$  by proper selection on the value of the measuring resistance.  
 Figure 1. Virtual instrument architecture

**3.2 Signal conditioner**  
 Signal conditioning in the current module is rather simple if compared to the voltage module. The Hall Effect current transducer provides galvanic isolation, while the operational amplifier (op-amp) AD711 is used to scale down the input voltages into the range of  $\pm 5V$ . In addition to that, the op-amp voltage gain ( $A_v$ ) is made adjustable by putting the feedback resistor ( $R_f$ ) as a variable resistor. By doing so, the current module could be easily calibrated.

The designed three-phase measurement voltage module can measure up to 500V. Therefore, the voltage needs to be stepped down before passing the signal to the electronic circuit. An easy way of stepping down the voltage has been determined by using the voltage divider. A high power resistor was used to provide 10V input to the voltage divider. Importantly, the DAQ system must be properly isolated to prevent damage to the expensive DAQ boards. Nevertheless, there are several known techniques for circuit isolation such as using optical, magnetic or capacitive isolator. For this purpose, capacitive isolation amplifier ISO122 was used, which provides 1500Vrms isolation between the measured signal and the output signal. The isolated dc-dc converter NMV1212S was used to provide supply voltage ( $\pm 12V$ ) to the isolation amplifier that eliminates the ground loop between the measurement signal and the supply voltage signal by  $10G\Omega$  resistance. Figure 5 shows the block diagram.

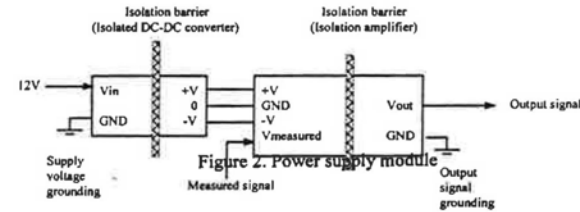


Figure 5. Block diagram of voltage module isolation

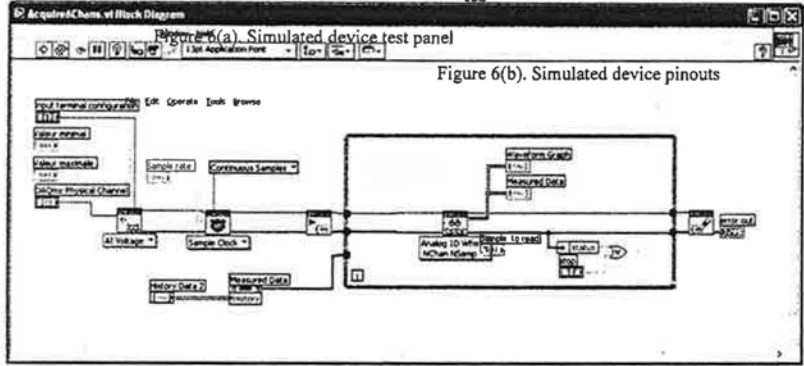
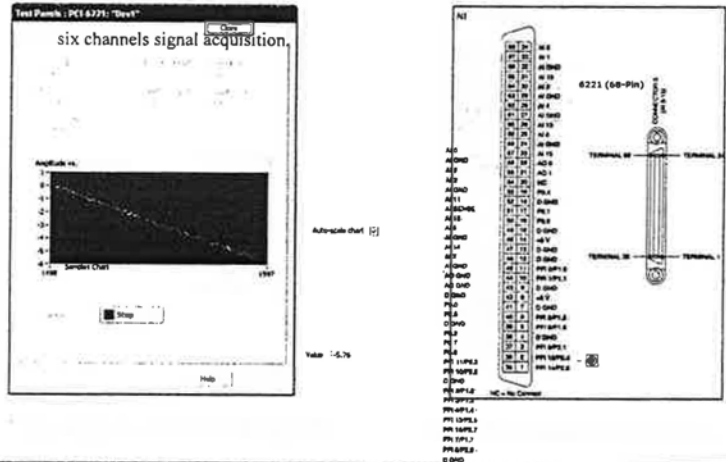
**3.3 Data Acquisition Board**  
 The capabilities and accuracy of the DAQ product depend on the number of channels, the sampling rate, the resolution and the input range. The low cost NIDAQ board (PCI-6221) from National Instruments was used as the data acquisition device that is fully compatible with the LabVIEW software. The important specifications of the board are tabulated in Table 1.

Table 1. Specifications of PCI-6221

PCI-6221	Specifications
Analog input Channels	16 single ended
ADC resolution	16 bits
Sampling rate	Figure 3. Current module Maximum: 250 kS/s Minimum: 0 S/s
Input range	$\pm 10, \pm 5, \pm 0.2V$

To avoid the aliasing problem, the sampling rate of the interface ADC must have at least 100Hz for a 50Hz mains frequency (Nyquist theorem). However, a good rule of thumb for quality sampling is to sample 7-10 higher than the highest frequency of interest, in this case  $50Hz \times 10 = 500Hz$ . The PCI-6221 DAQ board provides a maximum sampling frequency of 250 kHz, if all the 16 channels are used simultaneously, the sampling frequency per channel will reduce to approximately 15kHz. This sampling rate is still far within the required range of 500Hz.

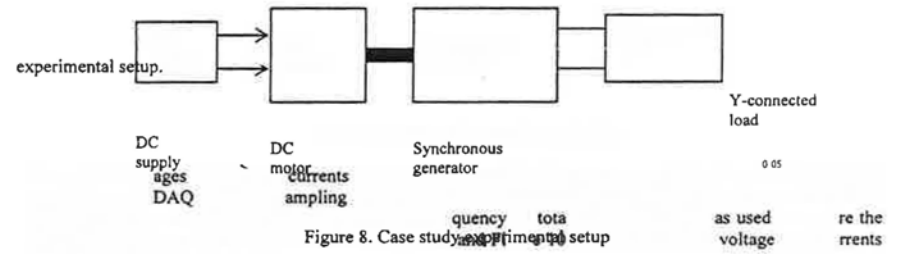
In the software development stage, the VI was first developed using the function of NI-DAQmx simulated device whereby the real PCI-6221 card is not actually slotted into the PC. This function enables LabVIEW to inherit the real PCI-6221 specifications. Figure 6 shows the test panel and device pinouts of the simulated PCI-6221 device. When the VI was successfully compiled in the LabVIEW using the simulated device, it enabled the VI to be tested in the PC slotted with the PCI-6221. Figure 7 shows the block diagram of the developed VI for



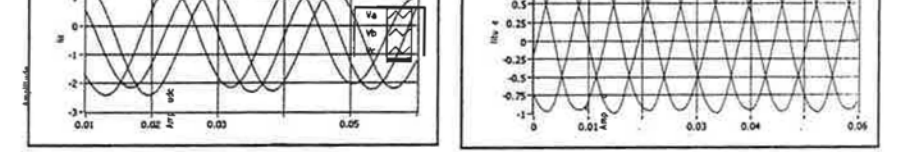
Before connecting the signal source into the DAQ device, special attention must be paid to the input terminal configuration in the NI-DAQmx task. There are three modes that need to be correctly selected depending on the application signal source, namely differential, referenced single-ended (RSE), or non-referenced single-ended (NRSE) mode. For the output floating signal source from both signal source and voltage module, the selected measurement mode is differential mode. It offers the advantage of common mode rejection which eliminates noise that is present on both leads thereby improving the signal to noise ratio.

The data logging feature are saved as text documents and can be viewed using LabVIEW data logger software. The data logging feature can also be accomplished using LabVIEW data logger software. The data logging feature can also be accomplished using LabVIEW data logger software. The data logging feature can also be accomplished using LabVIEW data logger software.

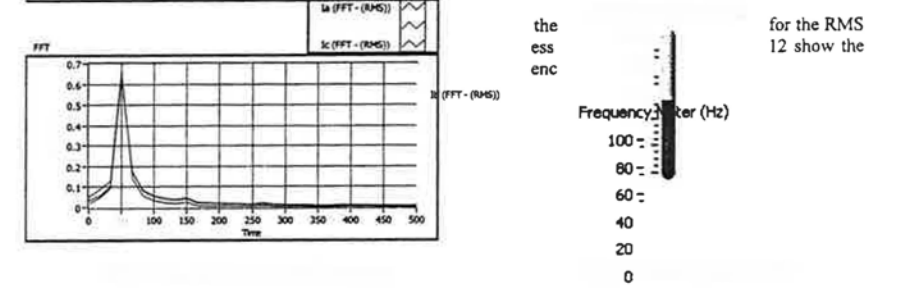
The case study was carried out based on the following experimental set-up. A DC motor, acting as the prime mover was coupled to the synchronous generator. The synchronous generator was loaded with the Y-connected load. Both the DC motor and synchronous generator had the rated value, of 220 V. Figure 8 shows the experimental setup.



The output voltage and output current of the Y-connected load were connected to the developed signal conditioner and device. A sampling frequency of 10 kHz was used to sample the signal source of 50 Hz. A total of six channels were used to acquire three-phase voltages and three-phase currents. Figure 9 shows the acquired three-phase voltages of the Y-connected load output.



For the frequency measurement, the FFT algorithm was called from LabVIEW function, while computation, LabVIEW provided the amplitude measurement expression. Figure 9 and Figure 10 show the measured frequency spectrum together with its RMS value and frequency meter respectively.



For the phase difference measurement, a power factor VI was developed. Figure 13 shows the line voltage ( $V_{LL}$ ) and phase current ( $I_L$ ) waveforms of the purely resistive Y-connected load. In Y-connected load, the line voltage leads the phase voltage by  $30^\circ$  whereas for purely resistive load, the power factor is close to unity as depicted in Figure 14. Figure 15 shows an example of data logged in Excel.

Figure 16 respectively.

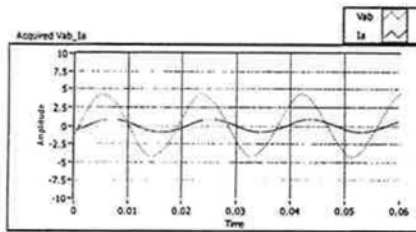
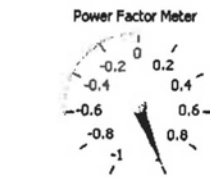


Figure 13. Load voltage and current waveforms



phase difference (Vab, Ia)  
29.9904

Figure 14. Power factor meter

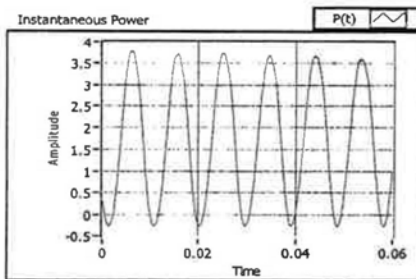


Figure 15. Instantaneous power



Figure 16. Data logged in Excel

## Conclusion

This paper described the development of hardware and software of a three-phase virtual instrument measurement system. The developed VI in LabVIEW enables extra computation of the acquired signals, such as RMS, power factor and phase difference which is impossible in the conventional oscilloscope. The LabVIEW also made the data logging an easy task. The case study showed the successful implementation of the developed system.

## Acknowledgement

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