Hands on Experience for students on an Energy Management System

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Abstract

As new energy technologies arise, they are being implemented in the Power Grid nationwide services. We believe that it is very important to create an efficient way to manage the energy resources in our facilities.

We have designed a system using the Graphical User Interface of LabVIEW to gather Solar Power Data using a Measurement and Computing minilab 1008 interface.

This system gathers Solar Power Information from a 5 kW Fixed Photovoltaic Array. It has the capability to retrieve real time prices of electricity for the southern region of Texas according to The Electric Reliability Council of Texas (ERCOT), and generate a report on the actual energy production revenue.

In this paper we introduce a set of experimental laboratory exercises for undergraduate students to become familiar with these practices of Renewable Solar Energy.

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Introduction

We have implemented a data acquisition/energy management system (DA/EMS) for a 5kW photovoltaic array system. Our main goal with this system is to improve the education of our undergraduate and graduate students about these arising technologies that are being implemented in our world today. Our DA/EMS has various hardware components including sensors, a data acquisition interface, circuitry implementation, loads, and the Photovoltaic system itself.

The software being utilized for this project is a graphical user interface (GUI) designed in LabVIEW. The data acquisition part of the project is compound of a variety of sensors that send information to the data acquisition interface, which is a minilab 1008 connected to the computer via USB. The data is read and processed through LabVIEW. The energy management system is mostly implemented through LabVIEW as well. In addition to our photovoltaic system, we have integrated a Solar Irradiance instrumentation laboratory, which provides real time information regarding the solar resource at our site. This data is collected and displayed in our GUI.

An energy management system was implemented in order to create a micro smart grid in the future. A milestone that connects us to a smart grid is to have a smart meter with an energy management system.

In our case, we can consider the data acquisition for this system equivalent to a smart meter. In our EMS implementation, the system acquires the price of electricity in real-time. For obtaining such prices, we rely on the Electric Reliability Council of Texas (ERCOT) for information on the

electricity bulk price. "The Electric Reliability Council of Texas (ERCOT) manages the flow of electric power to 23 million Texas customers - representing 85 percent of the state's electric load." [1].

In this paper, we describe the data acquisition/energy management system implemented in our facility, how it has been designed by graduate students and will be employed as a learning tool for future generation of undergraduate and graduate students.

Photovoltaic System and Data Acquisition Hardware

Two photovoltaic systems have been installed on the campus. One of them is a solar tracking system is located on the South-Eastern part of campus, and a fixed one resides on the Engineering building's rooftop. The tracking system consists of two motorized platforms with 12 panels each, and a maximum power rating of 2.75 kW, summing up 5.50 kW for both arrays. The fixed photovoltaic array has 24 panels, with a tilt angle of 10°. The panels are connected in series and have a maximum rated power of 5.184 kW. This array power production is the one being monitored with sensors and the LabVIEW GUI. The array has a battery bank to store energy, and the excess power is dissipated into resistive loads. The diagram on Fig. 1 presents the details of this system.

The data being measured is generated from Direct Current (DC). Alternating Current (AC) monitoring and utilization will be implemented in the near future. The sensors being utilized are voltage dividers for voltage measurements and Tamura hall-effect as current sensors. The voltage dividers will be replaced with some LEM LV25-P voltage transducers which are more reliable and represent a safer alternative to half watt resistors. The Tamura hall-effect sensors will also be replaced by LEM LA55-P current transducers, because they produce outputs that are very low and the miniLAB 1008 data acquisition interface cannot read these small voltage levels.

In order to elevate the voltage level from the current sensors, an operational amplifier (not pictured) is being utilized for each current sensor, but is very impractical because it introduces unnecessary components to the system resulting in unwanted noise. Due to previous observations, a third order low-pass filter was designed and connected between the charge controller and the battery bank. Before we implemented this filter, our sensors were detecting AC harmonics going through this line into the batteries. An oscilloscope was used to confirm these harmonics and the filter was designed and implemented.

The newest instrument added into our system, is a Kipp & Zonen Solys II Solar Irradiance Sun Tracker. This instrument consists of three sensors, two pyranometers and a pyrheliometer, which are used to measure the Sun Direct Normal Irradiance (DNI), Diffused Horizontal Irradiance (DHI), and Global Horizontal Irradiance (GHI). These measurements are very important to us because we can determine the efficiency of our panels using this instrument.
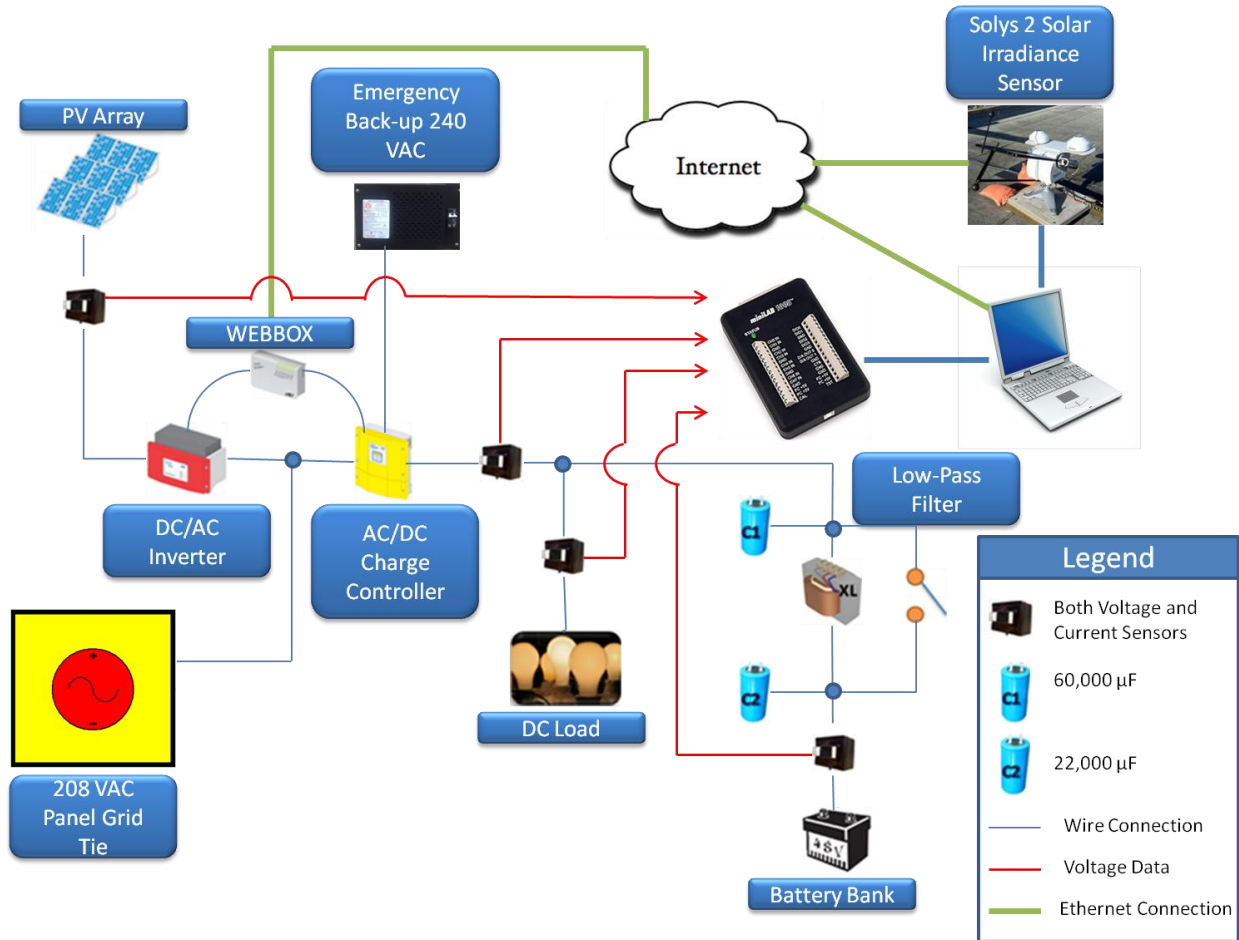
Figure 1 – Monitoring interface for Fixed PV Array system and Solar Radiation Laboratory

LabVIEW Graphic User Interface Description

For our data collection software, we decided to use the graphical programming of LabVIEW from National Instruments because we figured it would be very practical for us and simpler to update and utilize than other programming options. Another reason we decided to go with LabVIEW is the fact that we needed a good program that can read data, display it, make computations, control instruments, and be very flexible. A convenient feature of LabVIEW, is that it automatically produces a Graphical User Interface (GUI) or Front Panel, where we can view data and control it while the program is running. Figure 2 shows the GUI or front panel of the system.
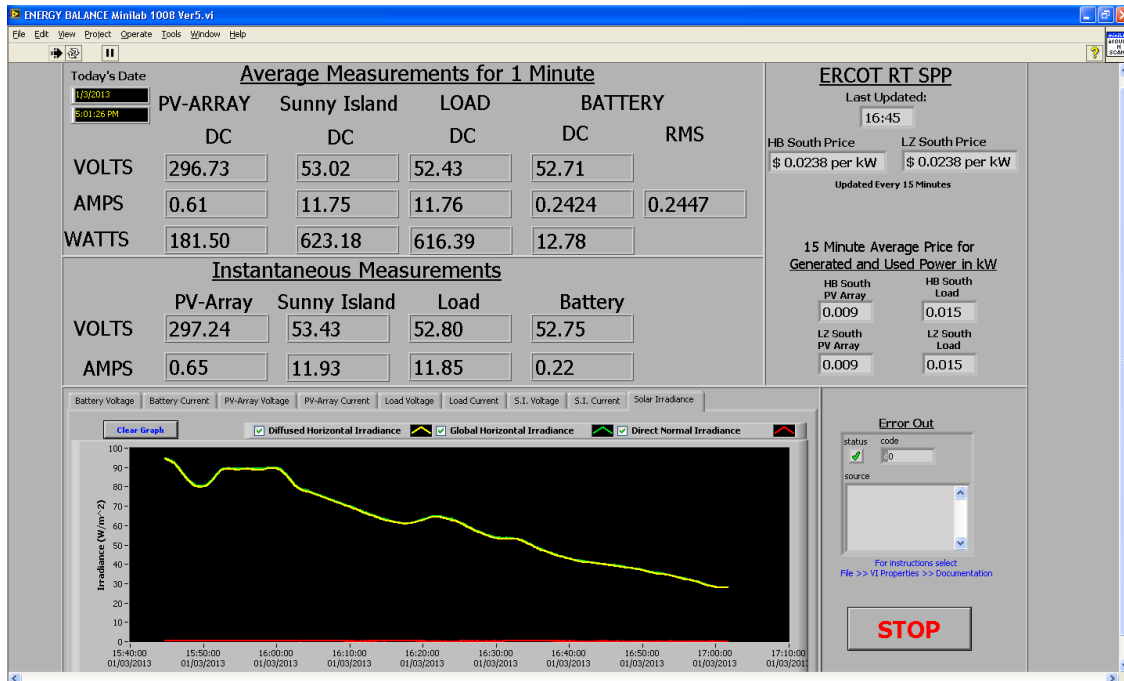
Figure 2 – Example of LabVIEW Front panel

Our GUI is separated into sections for ease of view. The program is set to take a measurement every second from all eight sensors being utilized; the measurements are displayed and graphed. This data is displayed on the Instantaneous Measurements section. There are multiple graphs in different tabs right under this section. These graphs display a 15-minute record history of what was measured, and are updated in real-time each second.

Included in these graphs is the Solar Irradiance graph, which displays all three Irradiances being measured by the Solys II. The Solys II is connected to the internet where it records its information and is later retrieved by software corresponding to the instrument on the computer.

Solys II software writes the information on three text files as comma separated values (csv) format every second, every minute, and every hour. Our LabVIEW program checks the file being updated every second and retrieves the data to plot it.

The top section is an average of 60 data samples updated every minute where the power and battery current RMS are calculated within the program. These averaged samples are also exported onto a text file in csv format which can be accessed at any time.

The right handed side of the GUI displays the current ERCOT price for both, Loading Zone (LZ) and Trading Hub (HB), for the Southern region of Texas. The Real-Time Settlement Point Prices (RT SPP) displayed on the top right corner are retrieved from the ERCOT website and are updated every 15 minutes by ERCOT.

LabVIEW is programmed to go check the website every five minutes to see if the data has been updated. Right under the ERCOT RT SPP section, we have a 15 minute averaged price for the electricity price being generated by the photovoltaic array and the power being dissipated on the loads. This is calculated by taking the latest 15 averaged samples of power from the panels, and load averaging them, and multiplying it by the current LZ and HB Price.

Student Technology Transfer

The main reason we have commenced this project is to have a hands on experience for our undergraduate and graduate students. As mentioned before, having a data acquisition system with energy management is a small step onto having a micro scale smart grid in our laboratory. Another main reason for developing this project is to have laboratories for student teachings, other projects, and master's theses. We are planning to have up-to-date laboratories and assignments with engineering tasks which are not taught in other courses. One of our laboratory assignment plans is to educate our undergraduate students in the programming software LabVIEW.

We feel that LabVIEW is becoming very popular in the engineering field and it is a good idea to have our students exposed to it.

We have developed a laboratory assignment which is a reduced form of our data acquisition system. This lab will introduce the students to instrument control via LabVIEW, data acquisition, and how to log their acquired data for future reference. The students are to use similar hardware (sensors, miniLAB 1008, and electronic circuits) to the ones being utilized for our system.

Using the information collected by LabVIEW from the Solar Radiation Laboratory, students can use calculations found in [2] to calculate efficiency of the solar panels. This can be implemented as another laboratory practice with hands on activity.

With the data gathering interface retrieving real-time information from ERCOT, the students can design an Energy Management System based on the price of electricity throughout the day. When the price of electricity triggers a set point for low cost, the student can decide to turn on specific loads using automation control within LabVIEW. If the price is higher, the student can choose to power off unnecessary loads and sell the energy being produced by the solar panels in order to get better revenue.

Student Assignments & Impact

The following learning assignments have been developed:

1. LabVIEW workshop and data acquisition
   Objectives

* What is LabVIEW used for?
* Implement a Data Acquisition system using MiniLab 1008 card
2. Analysis of the response of current and voltage sensors.
   Objectives:
   * Determine the response of Tamura and LEM model LA-55P Hall effect current sensors
   * Determine the response of resistive and LEM model LV-25P voltage sensors
   * Plot output-input characteristic curves and obtain best-fit linear equation
3. Datamining the PV array system. Analyze the energy performance by tapping the CSV files (1-min averages)
   Objectives:
   * Make 5-day plots of PV array and load powers.
   * Integrate 15-min kWh generation and consumption.
   * Calculate monetary value using ERCOT real-time settlement point prices.
4. Experiment the response of the system during loss of connection to the building's AC grid.
   Objectives:
   * Power emergency loads
   *Observe battery bank and charge controller behavior

We are still writing students Questionnaires to evaluate the impact of the learning materials on the students.

Conclusions and Future Work

With the implementation of a Graphical User Interface in LabView to collect data from the Photovoltaic Arrays, and the Solar Radiation Laboratory, the students from the University of are introduced to new technologies of Real-Time Monitoring interfaces that simulate an environment found in the outside world facilities.

By getting hands on experience with these technologies, the students can be better prepared for the challenging and demanding requirements on the engineering work field nowadays.

As future work, students can work in this project to add on capabilities for monitoring and logging AC Voltage interfaces. In addition, they can add diverse kind of loads (Capacitive, Inductive) that affect the Power Factor of the energy being generated, and a control system that compensates these disadvantages of electricity distribution found in real life.

The measurements described in [2], can be utilized in a near future to be implemented in the LabVIEW Interface in order to calculate efficiencies of the PV Arrays in real-time.

References

[1] ERCOT website - www.ercot.com/about/

[2] Leonel Aguilera, Jaime Ramos & Sanjeev Kumar, "UTPA Solar System Efficiency",

American Society for Engineering Education, 2012.