

# **AC 2010-1992: DESIGN AND IMPLEMENTATION OF A VIRTUAL WEB-BASED POWER MEASUREMENT MODULE FOR A HYBRID RENEWABLE POWER SYSTEM**

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# **Design and Implementation of a Virtual Web-based Power Measurement Module for a Hybrid Renewable Power System**

## **Abstract**

This paper presents the implementation of a hardware and software interface monitoring system for the power measurement and performance evaluation of a 4.54KW Solar/Wind combo Renewable Energy system designed for a Zero Energy Home. The project includes a *low cost, LED based power level indicator* working in conjunction with a *DC motor*, which is operated by the solar power system. The project also includes a fountain-like display showing the operation of a submersible pump placed in a 600-gallon tank and operated by the solar/wind power system. LabVIEW Virtual instrumentation was used for the dynamic data acquisition of the current and voltage outputs from the power system. The virtual instrumentation is configured to compute daily power output in KWhr; the output of which is interfaced to an embedded system for a digital read out and display of the daily power generation. A web accessible and remote controlled weather station is also configured for providing an elaborate histogram of weather data, including solar radiation and wind speed data gathered at the project site. The data logging is used for an assessment of the correlation between the local weather and the electric power generation.

## **Introduction**

The focus of the project is to provide a continuous monitoring channel for the 4.54KW hybrid renewable solar/wind power system and its electrical console, comprising of IO module “Grundfos 102” Controller, which has the property of combining both DC and AC to provide a single DC output signal, and is used to combine the total power from the solar and the wind turbine; EZ Wire 120 amp Controller system which combines two DC inputs and outputs the corresponding DC signal, Transformers, deep cycle batteries, 120V Xantrex inverter which transforms a DC input signal into an AC signal, and the Solar Tracker device Wattsun AZ-125, which helps the solar panel to track the sun, hence make the system more efficient. The power system consists of a solar tracking photovoltaic (PV) array and a Whisper H80 wind turbine. Detail integration of the PV modules, the wind turbine and electrical consoles with the monitoring interface system is discussed.

This project was a part of a continuing research on the renewable energy power based system that started in 2006. This phase began in summer 2009 and was funded by NSF, STEM, LSAMP programs. It was accomplished by junior and senior Electrical and Computer engineering students.

## **Zero Energy Visitor Center**



Figure 1. Zero Energy Visitors Center

The Zero Energy Home uses a 2.74 KW hybrid solar/wind system designed to generate its own electricity completely independent of the local power company. It demonstrates to visitors the use of solar energy and wind energy to deliver enough electric power to activate the appliances and electronic components in the visitor's center. It provides 24/7 information to visitors on the total power being delivered to the center.

In addition, it houses the weather station and the ongoing renewable energy projects on campus, and the LED Power Display, day-time attic exhaust fan, the HVAC, 42" HDTV, the mechanical control room, and a grid-tied system.

#### **Additional Solar/Wind Combo System**



This system was built and designed by University of the District of Columbia engineering students<sup>2</sup> and can operate on AC or DC voltage, and it supplies power to its own tracking system and a submersible pump that is both AC and DC.

In DC mode (Figure 3), the DC output is obtained by connecting the solar Array's DC output and the wind turbine AC output directly into the IO 102 switch. The IO 102 switch which will then output a single DC signal which will be used to feed a DC load (pump DC mode in our case).

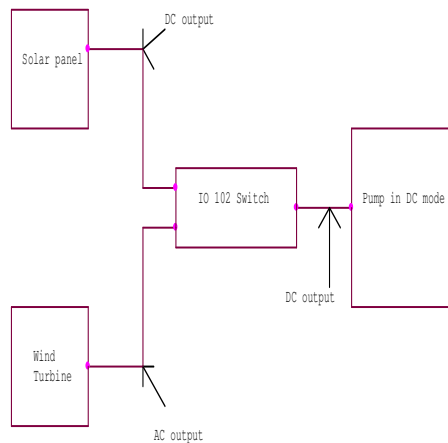


Figure 3. System connection in DC mode

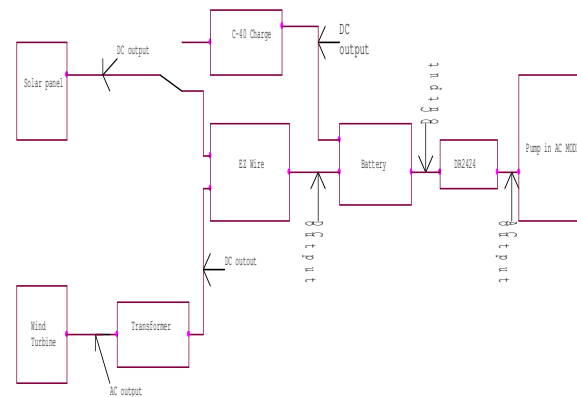


Figure 4. System connection in AC

In AC mode (Figure 4), the wind turbine AC output is transformed into a DC signal and combined with the Solar Array's DC output DC through the EZ wire. The single DC output of the EZ wire is then wired into the battery, which is later on wired to an inverter (DR2424) and the AC output is used to feed an AC load (pump in AC mode in our case).

## Weather Station

The Vantage Pro weather station is set up to monitor, record and forecast weather data at the Renewable Energy site. The Davis Vantage Pro2 Console collects and displays all weather data on its screen, from the Wireless Davis Integrated Sensor Suite (ISS). The weather station collects temperature, humidity, wind speed and direction, solar radiation, UV index, heat index, wind chill and several others.



Figure 5(a). Vantage Pro 2 Console



Figure 5(b). Integrated Sensor Suite (ISS)

The Vantage Pro2 can display up to 24 units of data, such as the last 24 minutes, hours, days, and months. When it is connected to a PC, using its WeatherLink software package it can log data every 10 seconds. The wireless ISS has a range of 400 feet through walls, 1000 feet line of sight.

**Other modules include** a system designed to be run solely or predominantly in the daytime, that will not be needed or rarely used in the night, such as, an attic exhaust fan which will be used mainly during the day to help keep down the temperature in the roof and operate solely on renewable energy in conjunction with a thermostat. A solar powered led display system to show an accurate reading of how much power is generated by the sun. It is designed with arrays of leds, transistors and resistors. It will power up only when there is an adequate amount of solar radiation, and can be calibrated for specific locations.

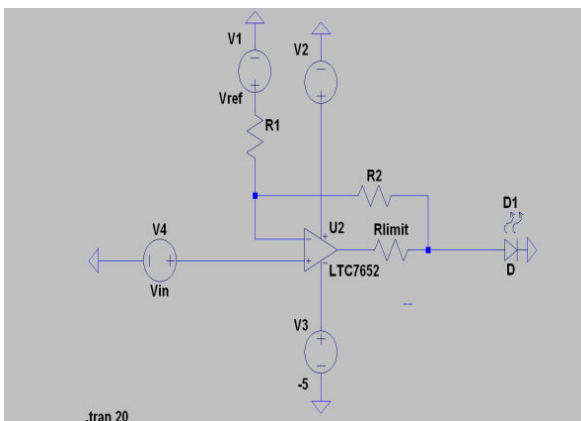


Figure 6(a). LED Power Display IC circuit

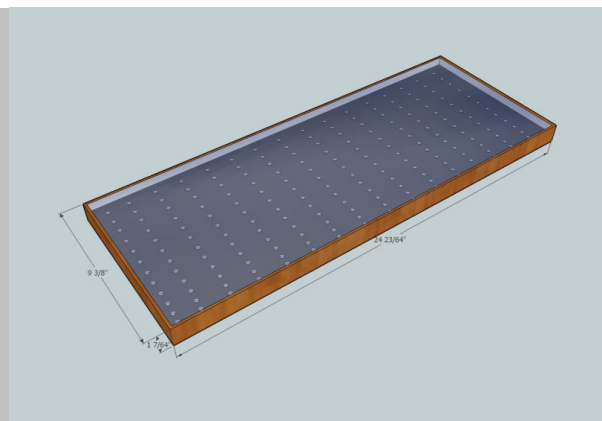


Figure 6(b). LED Power Display model

## Renewable Energy Data

The Zero Energy Visitors Center, Solar/Wind Combo System, the Weather station's data can all be logged and made viewable online.

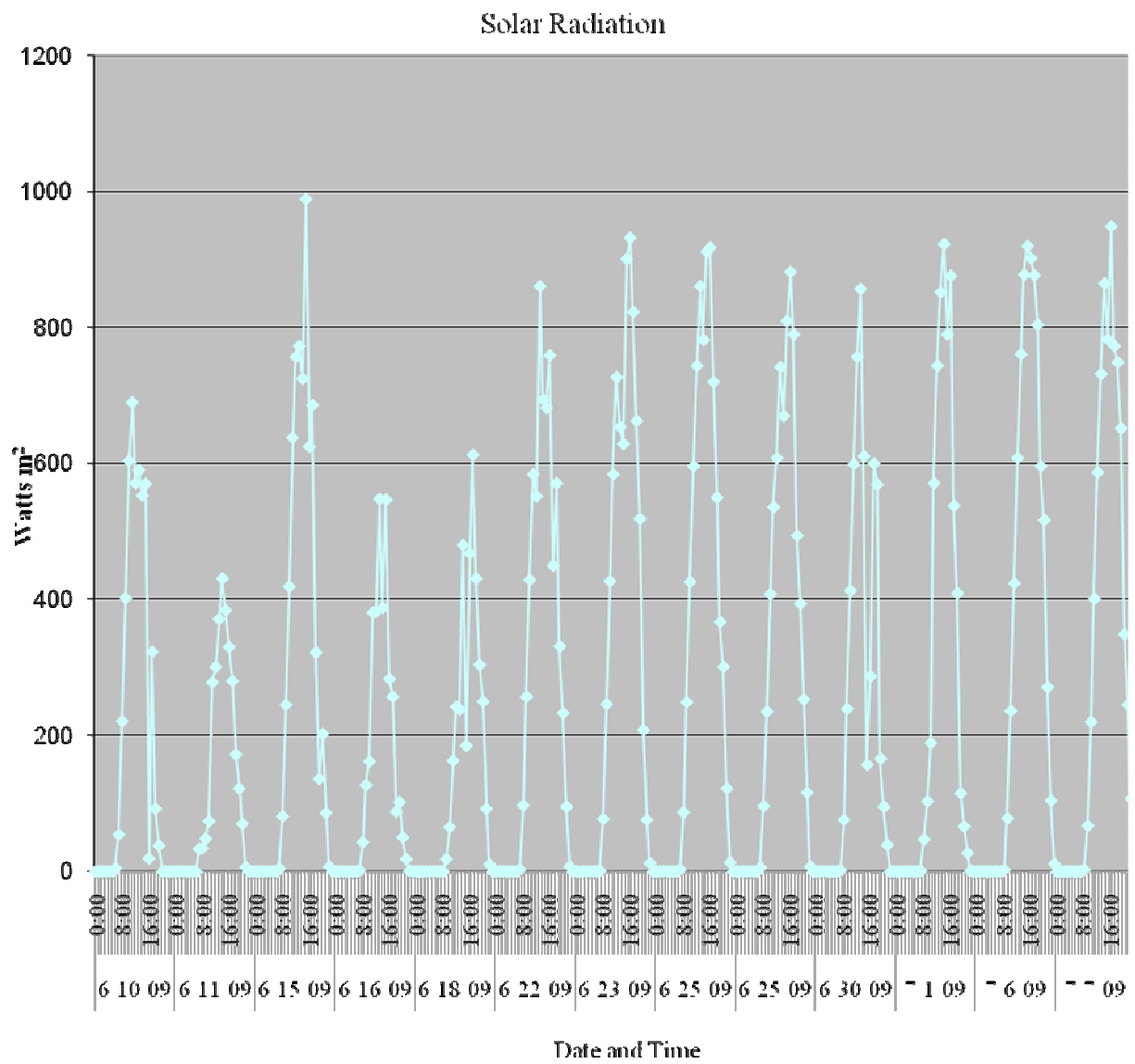


Figure 7. Solar Radiation

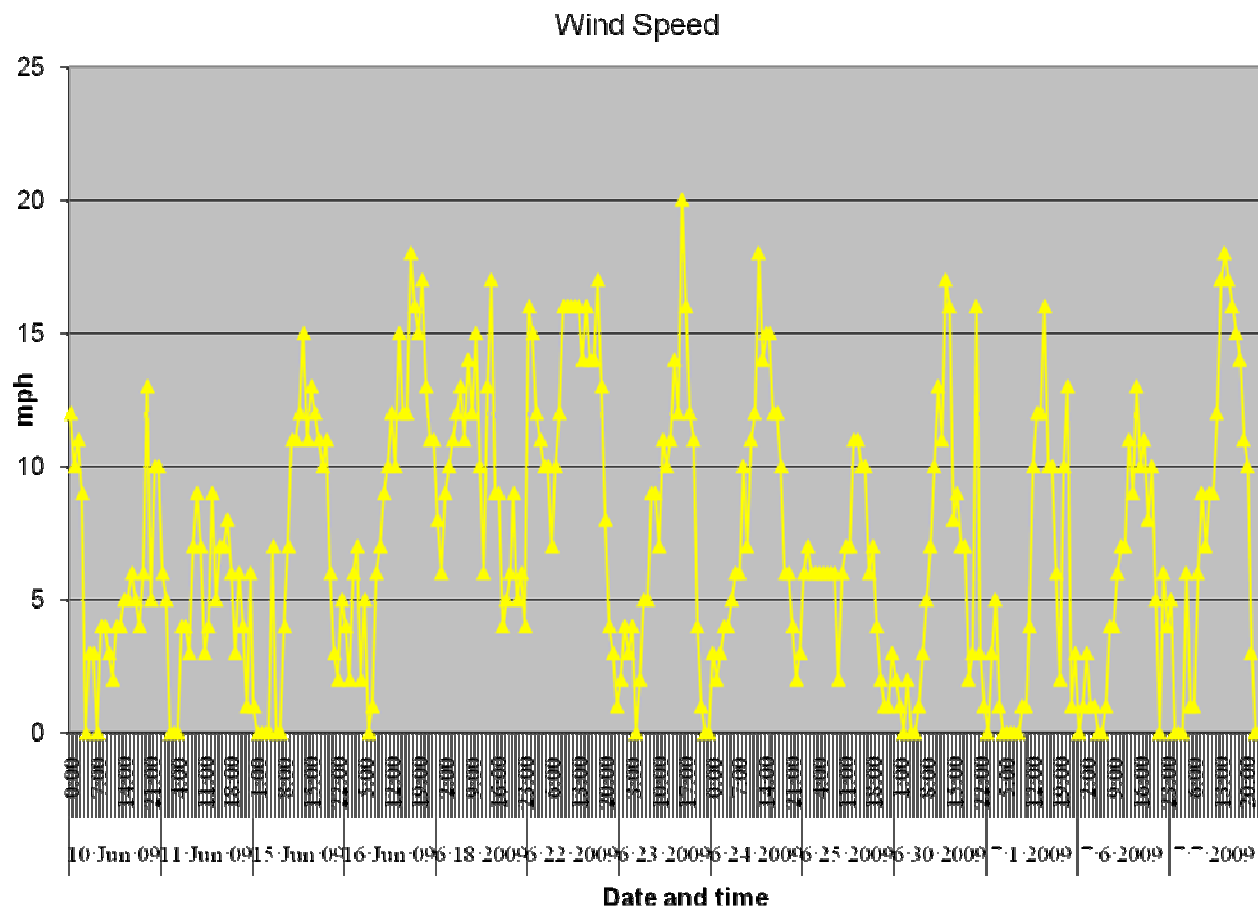


Figure 8. Wind Speed

Table 1. Estimated power output with average 6 sun hours per day (13.68kWh)

Date	System Power output kWh	Date	System Power output kWh
June 8	7.9	June 24	9.9
June 9	7.2	June 25	8.1
June 10	7.7	June 26	8.3
June 11	6.0	June 27	8.3
June 12	4.5	June 28	7.6
June 13	9.3	June 29	3.4
June 14	7.3	June 30	6.2
June 15	4.8	July 1	7.2
June 16	6.8	July 2	6.8
June 17	4.4	July 3	4.3
June 18	2.1	July 4	4.2
June 19	6.1	July 5	3.7



June 20	6.3	July 6	6.9
June 21	6.3	July 7	10.4
June 22	4.5		
June 23	7.4	<b>Total</b>	193.9

The performance data in the table (Table 1) is gathered from the charge controller in the Zero Energy home.

### Power measurement

The general expression of the power is given by the formula  $P(t)=V(t)I(t)\cos\theta$  where  $P(t)$  represents the instantaneous power at a time  $t$ ,  $V(t)$  the voltage across the load,  $I(t)$  the current flowing through the load and  $\cos\theta$  the power factor of the load. For reason of simplicity and in order to avoid the need of computing the power factor, we choose to measure the power when the system is set in DC MODE (Figure 3), which lead to a power factor of 1.

This design was done in multiple steps using different type of hardware and software. The first step was to obtain the value of the  $V(t)$  across the pump. In order to accomplish this task, we used the NI USB 4065 DMM, a digital multimeter which has the following characteristics

- Bus-powered for portability
- Small (7.0 by 4.1 by 1.3 in.) and lightweight (10 oz)
- 6½-digit resolution
- 7 built-in measurements - AC/DC voltage, AC/DC current, 2- or 4-wire resistance, and diode test
- $\pm 300$  VDC/ $V_{rms}$  isolation
- 3000 readings/s (maximum) at 4½ digits

The second step was to measure the current flowing through the pump. Due to the high current level, we use another USB 4065 along with the NI CSM-10A (Current Shunt Meter). The CSM allows the DMM to determine the current by measuring the voltage drop across a precision resistor. Therefore knowing the value of the resistor, the voltage across the resistor, we can easily compute the value of the current ( $I=V/R$ ).

The third step was to design a computer Program that will take the data collected from the DMM and compute the power. The software used for this task was LabView 8.6

LabView is a graphical programming software package used for measurement, control and automation. It is capable of interfacing a variety of computer board as well as other measurement instruments. In our design, LabView is receiving two signals, one from the 1<sup>st</sup> DMM (DMM1, Voltage across the pump) and the 2<sup>nd</sup> DMM (DMM2, voltage across the shunt). LabView, then compute the current using the value of the 2<sup>nd</sup> DMM with the value of the Shunt resistance. Once the value of the current is obtained, it is then used along with the value of the voltage from the 1<sup>st</sup> DMM to compute the power.

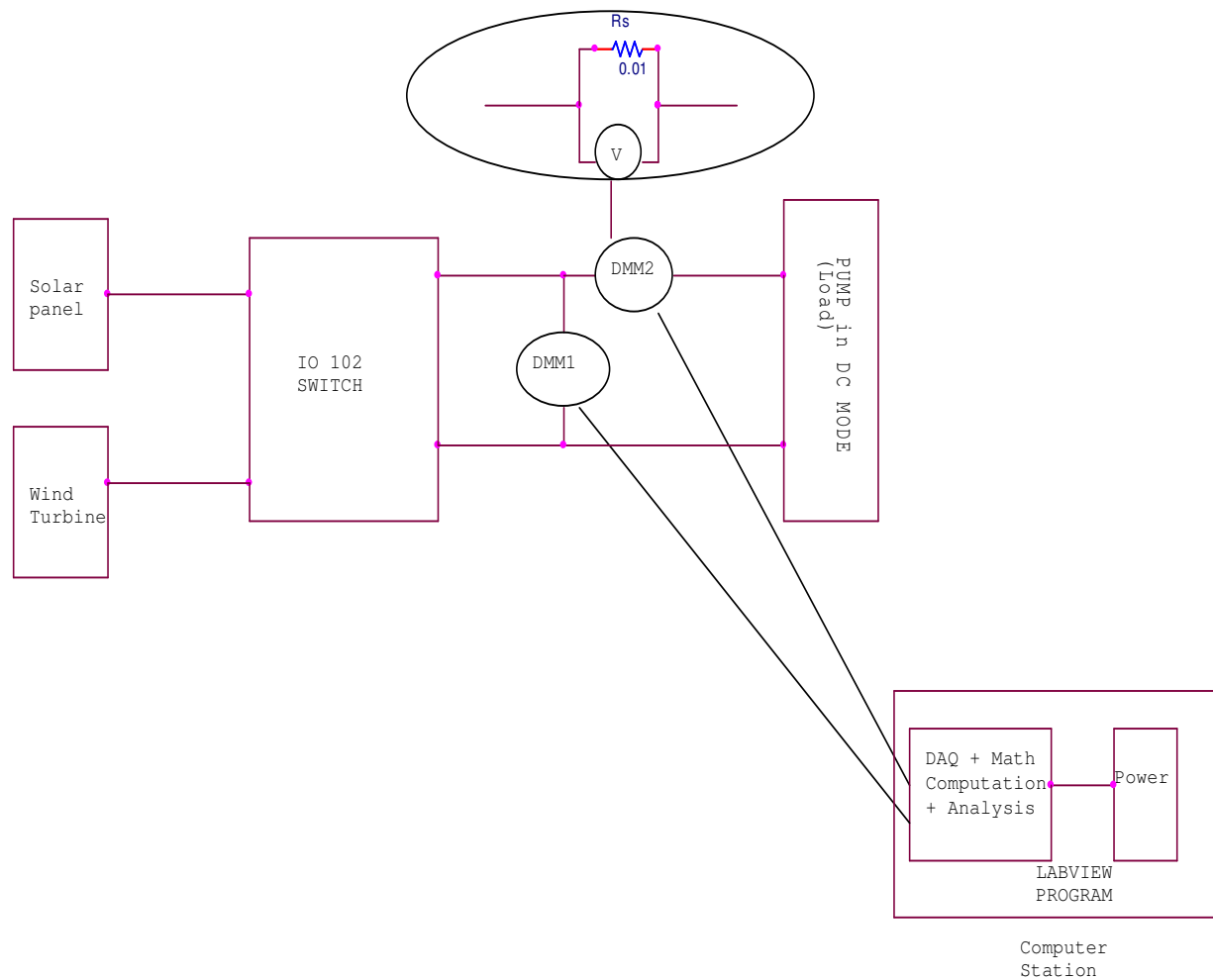


Figure 9. Power measurement design

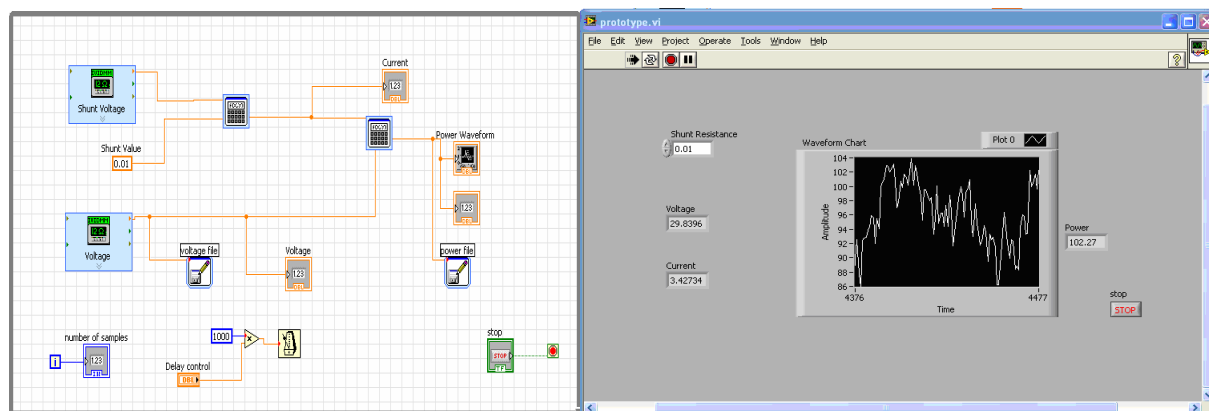


Figure 10. LabView block diagram design for power measurement

Work is in progress to configure a web-based LabView application where anyone with the appropriate address can log online and view the power produced, and a LabView driven display panel on the site that will display cumulative daily output power.

### **Cost**

The support for the major components from the following companies was instrumental in the building of the power system:BP Solar, Grundfos, Xantrex. Total equipment from NI Instruments cost approximately \$3000.

The construction of the Zero Energy visitors' center is supported by a grant from the DC Energy Office and cost approximately \$42,000.

### **Conclusion**

At this level of the design, we have successfully been able to dynamically and continuously monitor the performance of the solar/wind combo system, and configured smart meters that can be used to analyze the operation of the system on a daily basis. LabView also gave us the option to save actual cumulative data for comparison with the estimated performance data.

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