Development of a Renewable Energy Demonstration Building to Support On-line Training

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ABSTRACT An integrated data logging system was developed and installed at two locations utilizing renewable energy generation. The system provides real-world information that is used for student projects and examples in an on-line training program. This system gathers and stores a variety of real-time information in a centralized location. This data includes weather data as well as performance data for solar photovoltaic (PV), solar thermal hot water, and wind generation systems.

Combining information from all energy sources allows students and researchers to study the interactions between each generation component. The information is stored on an internet database where it is available to researchers and students through a secure login. A public website was created that displays real-time performance information of each renewable energy generation system. The building and instrumentation system provides data for a “virtual lab” to give on-line learners practical experience. Data collected over many seasons and years will be used to perform an economic analysis of the installed renewable systems.
Keywords: renewable energy, solar energy, wind energy, monitoring, on-line, training, web-based monitoring

INTRODUCTION

There has been increased interest in renewable energy lately and many home owners, farms and small businesses are investigating the employment of solar or wind technologies to supply all or some of their energy needs. Designers and installers have many questions about how to design, install and integrate systems, and how these systems perform in a Canadian climate and at northern latitudes. In an effort to provide some answers to these questions, Lakeland College constructed a small building (the Renewable Energy Cabin), intended to function exclusively using renewable energy technologies (Figure 1).

![Renewable Energy Cabin](image)

Figure 1 - Renewable Energy Cabin located on Lakeland College's Vermilion, Alberta Campus.

A modified shed package (4.1 x 7.3 meter) was built housing a small meeting room and research lab. The meeting room provided a needed load or demand for the renewable energy that was generated. The building operates off-grid and provides a realistic small-scale centre for applied research and demonstration of renewable energy technologies. The building employs 1.75 kW of photo-voltaic (PV) solar modules, and a 3 kW wind turbine for electricity. Evacuated-tube hot water solar collectors were used to supplement heat to the hydronic heating system used in the building. The building operates with no external energy input for all but the coldest months of the year.

The goal of this project was to have weather and system operational information measured and displayed real-time on a web server accessible through a website. The website contains a high-level display for the public and detailed information accessible to students and researchers through a secure login. On-line learners in the Renewable Energy and Conservation certificate program can log in to the Renewable Energy Cabin and observe the energy (both electric and thermal) generated, weather conditions, the heat requirements of the building, power consumption and calculate efficiency parameters. The Renewable Energy Cabin also provides data for a “virtual lab” to give on-line learners practical experience through lab assignments. Data collected over many
seasons and years is also useful in performing economic analysis of the various power generations systems.

SYSTEM DESIGN

**Electrical Generation:** As with most off-grid electrical projects, a load analysis for the building was performed. Electricity was required to operate two desktop computers, data logging equipment, hydronic heating pumps, lighting and other intermittent loads. Consumption was estimated and confirmed by measurement at about 195 kW-hr/month or about 6.4 kW-hr/day. For comparison, the power consumption of a 102 m² single family home was monitored over the same period with an average use of 643 kW-hr/month or 21.1 kW-hr/day. The square footage of the building was approximately 30 m² or about one-third the area of the small single family bungalow.

A solar photovoltaic (PV) array of 1.75 kW was selected to supply the base electrical load. The solar PV was configured with two 175 W modules mounted on a custom designed roof tilted to match the latitude of the site (53°). The remaining eight modules were mounted on a custom designed tracking pole that could track the sun from due east to west with 180° of tracking ability. The PV modules were configured for a nominal 48 volt DC system using an Outback Power® inverter to convert 48 VDC to 120 VAC electricity for the building.

Initially an inexpensive 2.0 kW micro-wind turbine was installed on a 12 meter tower to supplement the solar electrical generation on cloudy days or in the winter when the available sunshine was limited. The initial turbine failed after only eight months in service and was replaced with a better quality 3.0 kW turbine mounted on an 18.3 meter tower. Unfortunately, the second turbine failed after only 28 days in service due to a manufacturing flaw. The second turbine was repaired eight months ago and continues to work. Since the wind turbine seemed to be subject to mechanical wear and failure, it was only allowed to operate between October and March when the solar PV system had difficulty meeting the building’s electrical demand. A calibrated hall-effect current sensor was used to measure the DC current generated by the turbine. For demonstration, the performance of the installed turbine was compared to the manufacturer’s published data (Figure 2). Unfortunately, this turbine was located on campus and received turbulent air rarely at the 38 km/hr required for rated capacity.

![Wind speed response of Southwest Wind-power Whisper 500® wind turbine measured as an averaged sustained output for a 15-minute interval. November 14-17 2010.](image-url)
The solar PV and micro-wind generator directly supply electricity to meet building demand but also charge a bank of sealed gel-cell batteries. The batteries supply electricity through an inverter to meet building demand when solar or wind power is not available. The batteries were sized to supply approximately three days of autonomy.

**Space Heating:** The building was constructed using several wall designs. The north wall had sections with standard 89 mm wood frame construction (2.37 RSI), standard 140 mm construction (3.87 RSI) and a double 89 mm wood stud wall designed to eliminate thermal bridging (RSI 5.28). Type T thermocouples were imbedded in the inside and outside walls and ceiling at the surface to measure the temperature difference across each wall section. By measuring the temperature difference and assuming the constant thermal resistance, conductive heat loss can be estimated. The data was used by students to illustrate thermal conductive heat loss and building heat demand principles.

Heating demand for each month was estimated by using Natural Resources Canada HOT2000 software. A two-zone in-floor hydronic heating system was installed in the building. Energy for the heating system was supplied by a solar collector consisting of sixty evacuated solar tubes and supplemented with a propane water heater (Figure 3). The solar collection system has a rated capacity of about 2.4 kW. In addition to the solar hot water system a single 2 m² direct to air solar collector was installed vertically on the south facing wall of the building. This unit circulated room air through the collector and back into the room on sunny days. The solar air system would add approximately another 1.0 kW of heat during the day typically raising the temperature of the circulating air from 20°C to 50°C.

A 4500 litre insulated underground water storage tank was incorporated to store excess heat generated by the solar system in the summer.

![Figure 3 - Schematic of solar hydronic heating system with storage tanks](image)

The solar heating system supplied the building’s heat requirements entirely for the period from April to October while supplying 5% of the required building heat in January and 51% of the requirement in March (Figure 4).
Figure 4 - Predicted heating demand compared to actual heat produced by air and fluid solar collectors for 2010.

**Data Acquisition:** One of the main objectives of the project was to collect performance information from the solar PV, wind turbine, solar thermal system, building components and site weather data to make the data available to students via the internet. Many wind and solar energy systems provided their own data collection and retrieval systems, but do not integrate well together. Better integration of data was necessary. For example, to generate the graph in Figure 2, data was required from both the wind turbine and the weather station. An integrated system was required to create a central location where data could be displayed or queried. An integrated data collection system was devised with the flow of information as illustrated in Figure 5.

A program was written in C# to read data from the Outback® solar PV inverter system, parse and store the data in a comma separated variable, (CSV) file on the desktop computer located in the renewable energy cabin. Commercial software available for the Davis® weather station and Campbell Scientific® data logger was configured and used to gather data from those sources. In addition, data was collected from The Energy Detective® (TED) power management monitor from its built in web server service. Software was written in Java to centralize the data coming from the multiple sources and upload it to a web-based MySQL database. The upload software also provided summary calculations from the raw data and generated graph images for display on the web page. The upload structure could be modified easily through a user interface on the local computer. Five-day graphs displayed on the web page included daily accumulated PV electrical energy produced, wind power, solar thermal power (both hot water and hot air systems), selected temperatures, and glycol flow rates. Historical 15-minute data dating back to September 2009 was available through the secure login system.

In addition to the web-based database, a second mirror database stored a copy of the information on the local computer. In the event of a network failure, data would be stored locally, and then when communication was restored, the web-based database would be updated.

The web page (www.lakelandecabin.ca) was enhanced with animations that changed with the data, dynamic user-selectable graphs, and a three-dimensional tour of the cabin with picture galleries.
The intent was to provide quick graphical display of data to the casual user while providing detailed information for applied research and student use.
Expansion – Visitor Centre: The original renewable energy cabin was designed to demonstrate an "off-grid" situation. Recently, a similar integrated information collection system was designed and installed at a visitor centre in Elk Point, Alberta that incorporates a "grid-interactive" solar and wind installation. The data from this site is similarly available to the public and to students. In this system an eGauge® power system monitor was used to measure AC power generated by the 2.4 kW wind turbine, the 2.4 kW solar PV system as well as power to and from the utility grid. The eGauge® power system monitor provided a graphical output that was incorporated into the data web page. An example of the web display is given in Figure 7.
In Figure 7, the electrical energy demand of the building is plotted as the red line. Electricity consumption increases dramatically each evening as night security lighting automatically turns on. The combined renewable energy generation is illustrated by the area under the green line and varies with solar radiation and wind conditions. The dotted line in Figure 7 represents the contribution of the wind turbine to total generation. The area represented in white is the energy supplied from the renewable generation that meets the building’s load. The area represented in green is the energy supplied from the renewable generation that back feeds the utility grid. The area represented in red is the energy supplied from the grid to meet the demand not met by the renewable generation systems. The grid interactivity is easy to see using these graphical techniques. As this project continues, new ways to display the data will be investigated. Web-based animated graphics will be incorporated to show real-time data.

CONCLUSIONS/RECOMMENDATIONS

The renewable energy cabin project has met its objectives of integrating performance information from multiple systems into a single web-based access point. Students in the on-line renewable energy and conservation certificate program can monitor the system’s real time performance and use the archived data to confirm design estimates and diagnose system failures. One factor limiting the adoption of renewable energy systems is the lack of understanding for how component ratings can be used to predict actual performance. In some cases, solar or wind systems have been oversold leading to customer disappointment. By studying actual performance, students can learn how to better predict performance and gain an appreciation of the variability in the wind or solar resource.

This simple cabin project has created a platform to study the benefits of solar tracking, solar PV performance and temperature, the viability of solar space heating, thermal storage techniques, building heat loss, and the synergies between wind and solar generation. Integrating the information from multiple systems allows students and researchers to study how multiple renewable energy systems can work better together. Students can also perform an economic analysis on the systems using actual performance data to evaluate the viability of off-grid and grid interactive renewable energy systems. The renewable energy cabin has provided distant students in on-line courses a practical lab that they can access via the internet.

The test buildings also offer applied research opportunities to enhance the integrated information system. The upload computer at the Elk Point test site has been replaced with a custom programmed dedicated single board computer that gathers information from the solar inverter, wind turbine and weather station more reliably and eliminates the need for a computer on site. The custom written software for the single board computer also communicates directly with all monitoring devices and weather station eliminating the need to simultaneously run multiple manufacturer-specific software packages.

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