A Multi-Discipline Undergraduate Renewable Energy Engineering Project

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KEYWORDS:

ABSTRACT: *The project is a good example of multi-disciplinary cooperation of different engineering disciplines as well as providing valuable hands-on experience. In addition to providing useful lessons in teamwork and project management, the project will provide a working demonstration wind and solar energy system. It will be designed to allow in-service testing of various types of solar trackers and concentrators, wind turbine generator designs, controllers and system design optimization as developed earlier at the University of Western Sydney.*

1 INTRODUCTION

Renewable energy sources, like solar, geothermal and wind energy, are abundant and cause little harm to the environment. Using renewable energy can be as simple as designing a building to face south to take advantage of heat from the sun. In order to halt the greenhouse effect and clean up the smog-filled air that rests above our cities, we must begin to use our energy more efficiently and move quickly towards a more diversified energy mix, taking maximum advantage of clean, renewable sources. The solutions are at hand. What is needed is education and action. Interest in renewable energy has been growing steadily over the past 20 years. Today few would perceive a future without the renewable contributing to our energy provision and many believe that renewable energy will make a substantial contribution to our energy supplies in the longer term.

The University of Western Sydney (UWS) is pursuing a broad environmental research program in water quality management. The retention pond project forms a part of this overall program. The University has also been involved in renewable energy system research and the project provided an excellent opportunity to satisfy both agendas

It is often difficult to provide useful, hands-on practical experience for students as part of their engineering degrees. This project involves elements of structural design and fabrication, watercourse management, and electrical, electronics and computer engineering system design and fabrication. Being accessible to the public also means that the students have had to become aware of and apply relevant Australian building and electrical standards, eg AS 3000 [1].

The electric power system will be a self-contained renewable energy system with solar panels, a wind generator, regulator and battery storage. The solar panel pedestal and base and wind turbine tower will be designed to allow for ready replacement and/or modification of panels, wind machines and other devices such as solar trackers in a modular format. As such it will provide a convenient fully operational test-bed for further student and research projects. In particular, it will allow for the testing of designs for small, efficient roof-top wind generators [2,3] and trackers. A system controller/regulator will also be part of the project, rather than using commercially available ones, to enable the development of "intelligent" controllers [4].

2 PROJECT DESCRIPTION

The project is associated with storm-water runoff control and quality improvement and involves a circulating water system in a series of water retention basins along a seasonal watercourse in the University campus. The primary objective is to raise water oxygen content and avoid stagnation during long dry spells. The project enabled engineering students of several disciplines to come together as a team to develop solutions to water run-off quality management as a part of a broader environmental sustainability research effort at the University.

The water circulating components will consist of a water pump, powered by wind and solar energy sources in the larger of two ponds. It involves design of a stand-alone renewable energy system, with wind turbine, solar panels, system regulator, energy storage and performance monitoring/data logging components. Civil and environmental students will be involved with overall hydraulic design and design of towers and structures.

The main point of this project is designing a water filter (pump) to filter a pond at University of Western Sydney, in Werrington South (Figure1).

Figure 1 – Pond Involved in the Project

The water pump gets it energy from a battery, which is powered by 2 natural sources, wind and sun. An AIR 403 Wind Generator, and solar panels are used in this project. Both solar panels and wind generator are connected to the battery. The AIR 403 is using AC voltage, and the battery is DC. Therefore we have to use a variable AC DC converter between the wind generator and the battery.

2.1 CHARACTERISTICS OF THE 403 WIND GENERATOR

*Rated Output:	400 Watts
*Rated Wind Speed:	45 Kmph
*Rated Rotation:	2000rpm
*Cut-In Wind Speed:	10Kmph
*MO. KWH/ 16Kmph:	47kWh
*Percent Rated Output:	16%
* MO. KWH/ 19Kmph:	6kWh
* Percent Rated Output:	23%
*Rotor Diameter:	1.3m
*Number of Blades:	3
* Type Generator:	PM Alternator

How far above the ground the AIR 403 should be? The higher the wind generator is from the sea level, the lower the air density. Werrington is around 105 meters above the sea level. For the Air 403 generator, the average wind speed is 19Kmph at 30 feet (10 meters). The height of the air generator should be between 7 and 10 meters.

The best time to run the project during the year is in December. According to the weather observatory in Penrith, December will have the most wind during the summer season. The solar panel will get the maximum power output during the summer, when the day is long and the sun is always shining.

2.2 COMPONENTS OF THE PROJECT

- Wind Module
- Solar Module
- Solar Tracker
- Real Time Power Measurements
- Maximum Power Point Tracker/Controller
- Data Logging System
- DC-AC Inverter

The pond is part of the water retention basin system on a small seasonal watercourse in the University of Western Sydney (UWS) grounds, that was required by the local council planning approval process associated with a new university building nearby. It was decided to take advantage of the need to construct a retention pond to develop a working environmentally based runoff water quality control system.

Located nearby was a small compound and large shed associated with a separate soil erosion project. This structure provided a convenient secure location for the batteries and control equipment.

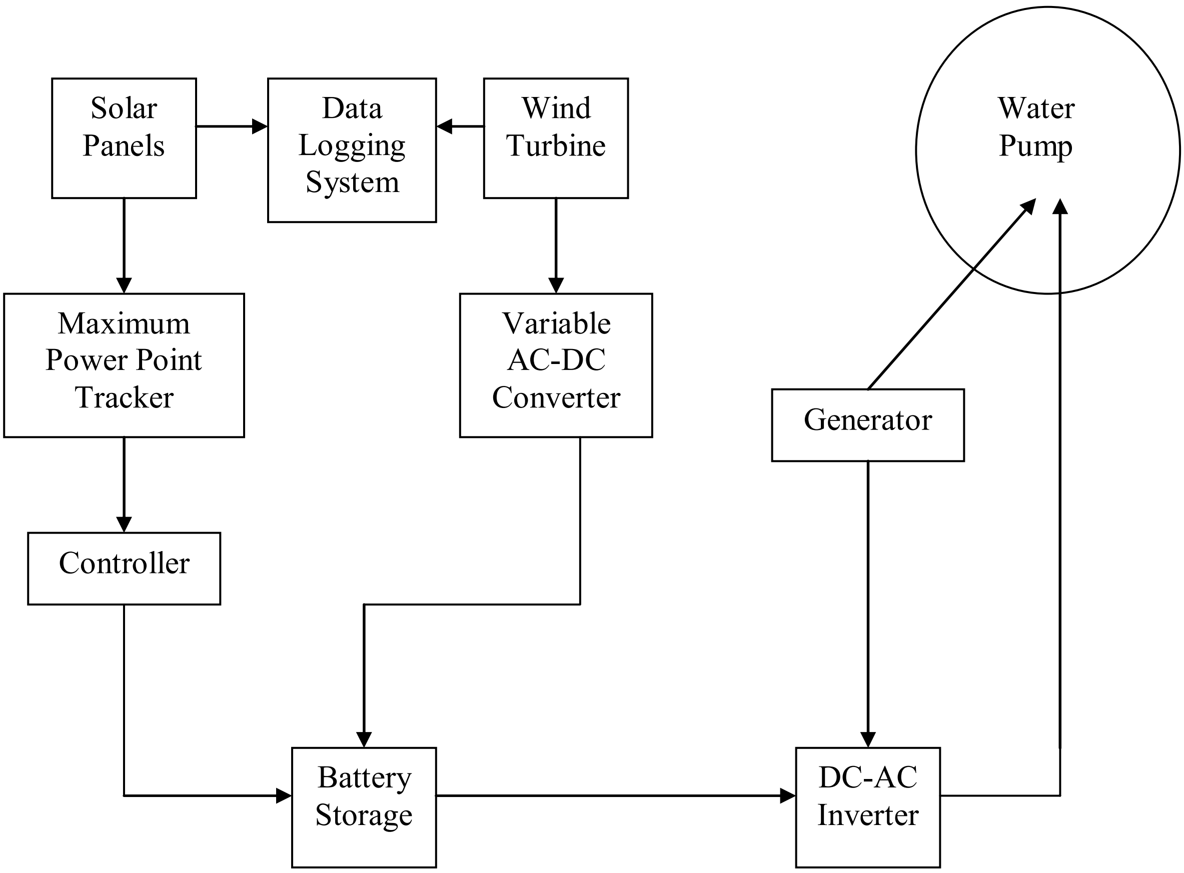

Figure 2.2 – Wiring Figure of the Project

3 MULTI-DISCIPLINARY INPUT

The school of Engineering and Industrial Design at University of Western Sydney has students from different Engineering disciplines: Civil, Environmental, Computer, Electrical, Mechatronics and Telecommunication Engineering. Students from few engineering disciplines will be involved in this project.

3.1 CIVIL AND ENVIRONMENTAL

The civil engineering input to the project covered the design of a pontoon that will house a submersible pump, the solar panel pedestal and wind turbine tower, pedestal and tower footings, and structural and wind loading analysis.

- The civil engineering group also provided overall project management.
- Environmental engineering input covered the analysis of the water flow and required water circulation flow volumes.

3.2 ELECTRICAL AND ELECTRONIC

The electrical engineering components of the project were -

- Overall design, choice of pump, operating voltage, AC or DC and wire type and size.
- Design of solar module, including solar tracker base, and tracker micro-controller. Two existing 80W polycrystalline panels were available
- Design of wind module and connection to system. An existing 400W "Air 430" generator was available
- Design of battery, controller and regulator. The latter included the maximum power point controller for the solar module, logic to switch in and out the wind and solar modules, shunting of the wind generator in periods of high winds, and restricted operation of the water pump based according to battery state of charge.

3.3 COMPUTER

The computer engineering components of the project were -

- The design data measuring/acquisition devices, for slow real-time data capture of solar and wind module outputs
- The design of a data logging system, to accept this data and store it for later analysis.

4 PROJECT MODULES

Descriptions of the main electrical project modules is given below:

- **Demonstration Renewable Energy System – Overall System Design**

A demonstration renewable energy system, containing wind, solar and storage components, is proposed as part of the environmentally sustainable systems research project at UWS. The objective of this module is to demonstrate sustainability in a practical way and is built around a water retention pond. As part of this project it is proposed that a 1kW model of a renewable energy system containing all major components be built, in order to drive a water pump in the pond to help filter the water. Parts are now on site, including an "Air 403" 400W wind generator, 4 x 6 volt batteries, a single phase modified square wave inverter and a Solarex 80W solar panel.

A 50A 48V DC main switch has also recently been purchased. A steel base to secure the wind turbine has to be fabricated in the workshop.

- **Wind Module**

In this module, an "Air 403" wind turbine will be erected and connected to the system. This project will require connection and monitoring of output. One of the outcomes of this module could be the design and development of an electronic device to sample and measure power output and to store this information locally in a small microprocessor for later upload to a personal computer.

- **Solar Module**

In this module, the PV solar panel will be erected and connected to the system. This will involve design of a single-axis tracker platform on which to mount the panel, design of a suitable pedestal (in conjunction with civil), design of tracking system based on stepper motors and micro-controller, and connection to the battery. Monitoring of output is also required. The outcomes of this project could be:

- Design tracking system, based on a micro-controller containing an on-board date/time routine. The panel will be re-positioned every 15 minutes. Use as small a sized stepper motor as possible, to conserve energy. The motor should be able to park the panel in a fixed position without drawing power in between repositioning.

- Design and develop an electronic device to sample and measure power output and to store this information locally in a small microprocessor for later upload to a PC

- **Hinged Variable Solar Tracker /Concentrator**

Solar PV cell output varies almost linearly with solar irradiation. Most solar panels are fixed in orientation, which means that in the early or late hours of the day, the output decreases due to the obliquity of the sun's rays to the panel. One solution is to use solar tracking devices, however two-axis trackers are expensive, requiring additional structures to hold the panels. Most panels in an urban setting will be placed on roof-tops, which have a fixed orientation. Roof-mounted tracking devices would be unacceptably ugly. One solution is to use a single axis tracker, with hinged reflector panels, to follow the sun from east to west during the day. With such a system, some solar concentration can also be achieved, increasing output, especially near noon. In addition, most tracking concentrators only have a fixed concentration ratio, whereas hinged panels offer some control over the amount of concentration used.

The down-side is that as irradiation increases, so does cell temperature and this causes cell output to drop. Without extensive cooling arrangements, there is a trade-off between irradiation and cell output.

There are two objectives of this module:

1. Build a simple hinged single-axis tracking solar concentrator to prove the concept;
2. Experiment with varying levels of concentration, with the aim of developing a control routine that will optimise output, by balancing incoming irradiation levels against cell temperatures.

- **Energy System – Real-Time Power Measurement**

The goal of the sustainable energy system program at UWS is to develop methods to optimise system design and develop control routines to maximise use of the renewable energy resource generated. One major issue is that the renewable resource (wind and solar energy) is always fluctuating and ways to measure this so as to operate the wind and solar modules at maximum power point are needed.

The objective of this module is to build a device to do "slow" real-time power measurement, in a DC circuit (eg the rectified DC output from the wind module and the solar module).

- **Demonstration Renewable Energy System – Combined Maximum Power Point Tracker/Controller**

The goal of the sustainable energy system program at UWS is to develop methods to optimise system design and develop control routines to maximise use of the renewable energy resource generated. One major issue is that the renewable resource (wind and solar energy) is always fluctuating and ways to measure this so as to operate the wind and solar modules at maximum power point are needed.
Commercially available solar regulators (the more sophisticated ones) embody maximum power point (MPP) trackers. In recent times, some research into MPP trackers for wind generators has been taking place. As all renewable energy systems involve a controller/regulator (to control flow of energy into storage and the DC/AC inverter to loads), there is an opportunity to combine the MPP and controller functions into the one device.

The objective of this module is to build a maximum power point controller for both the solar panel and wind turbine.

This will involve some form of real-time power measurement, so could be a project to be run in conjunction with Modules #1 to 3.

- **Demonstration Renewable Energy System – Data Logging System**

One of the goals of the UWS renewable energy system research is to expand the applicability of renewable energy systems. Increasingly, many of these systems will be grid-connected. One of the issues concerning grid connection is the fluctuating nature of the renewable resource (wind gusts and cloud shadows) and the impact these may have on the electricity grid [5,6].

A useful project would be to obtain data from physically dispersed generation sources to measure the interaction of the sources and the fluctuations.

The objective of this module is to build a cheap data logging system. The aim of the system would be to collect real-time performance information about the wind and solar modules in the demonstration renewable energy system project, in actual day-to-day conditions, as weather conditions vary.

Eventually a number of sites across campus may be set up (for instance to model the impact of moving cloud shadows). Therefore, a second stage of the project would be development of a system to collect data from several machines over the UWS internal intranet to load onto a central computer.

- **Model System Load**

The goal of the sustainable energy system program at UWS is to develop methods to optimise system design and develop control routines to maximise use of the renewable energy resource generated.

The construction of a model load which could simulate a real consumer load and to which wind and solar devices could be connected would assist the above goal.

The objective of this module is to build an electronically controlled "load" (to be controlled by micro-processor or PC interface), consisting of resistive elements, say a switchable bank of lights. The load should be variable so that typical customer type load cycles (e.g. domestic, commercial) can be simulated.

As at the date of writing, the overall project system design was essentially on track and had progressed to the stage that major components had been analyzed and designed.

A number of meetings between the participating students have occurred and the student's have completed their major reports required as part of the final year project work.

5 CONCLUSIONS

A multi-disciplinary final year undergraduate student project for the environmental management of run-off water, powdered by a renewable energy system, has been described.

The project has already shown benefits in terms of teaching teamwork, project management and practical design issues and has given the university a high level of confidence that the key project objectives will be met.

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