Interprofessional Project

IPRO 301
Solar Hydrogen Hybrid System
Fall 2004
Final Report

December 3, 2004

Abstract:

The photovoltaic/hydrogen hybrid energy system IPRO was started eight years ago. A group of students with their faculty advisor began a semester to investigate the use of solar energy to power an electric sign. Since that time, a significant amount of progress has been made. The project progressed from the design phase to the laboratory phase. Once functioning, it was transferred to the roof of the Co-Gen plant on the IIT main campus. During this phase of the project, Phase I, a photovoltaic system was set up that included several solar panels on the roof. Also, a large LED sign was installed on the roof. An array of power management devices were set up at the project site inside the Co-Gen plant. Phase II of the project was planned in order to incorporate an electrolyzer and fuel cell as an energy back up system in conjunction with the PV system. Although these components exist at the work site, they are not integrated into the complete system and are merely there to demonstrate using hydrogen to power an electric load.

Over this past summer, the site was not maintained and the various individual parts began to degenerate. The batteries could not hold a charge and the electrolyzer and fuel cell were in disrepair. This is where the Fall 2004 IPRO came in. It became our objective to debug the eight year project and restore functionality to the sign.

We began the project by splitting the previous IPRO groups' documentation amongst the members of the group to organize the documentation by system component and in an attempt to develop an understanding of how the system worked. Three groups were created: the sign group, electrolyzer/fuel cell group and data acquisition (DAQ) group. The team members on each group were assigned based on interest and ability. Goals were established and each group encountered many challenges in an attempt to meet those goals. The groups communicated at our Tuesday sessions and through status updates via the Yahoo! group.

Several goals were achieved this semester and will be discussed later in this report.

There were many lessons learned in this IPRO experience. Below are our top lessons learned:

- Do what we can, when we can.
- Communicate with fellow team members and supervisors.
- When we reach an obstacle that is beyond our scope of knowledge, bring in an outside expert to help further our project goals.

As a final note, we recommend that in a project of this magnitude that the teams leave appropriate documentation, which include lists of unfinished goals and clear direction to what they foresee needs to be done.

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Team Contributors

Undergraduate Members: James Baldwin, Roger Bacchus, Colleen Chapman, Micheal Condei, Brent Cucci, Waqas Jamal, Anh Luong, Leonardo Melo, Mohammad Mahmoud, Phil Newberg

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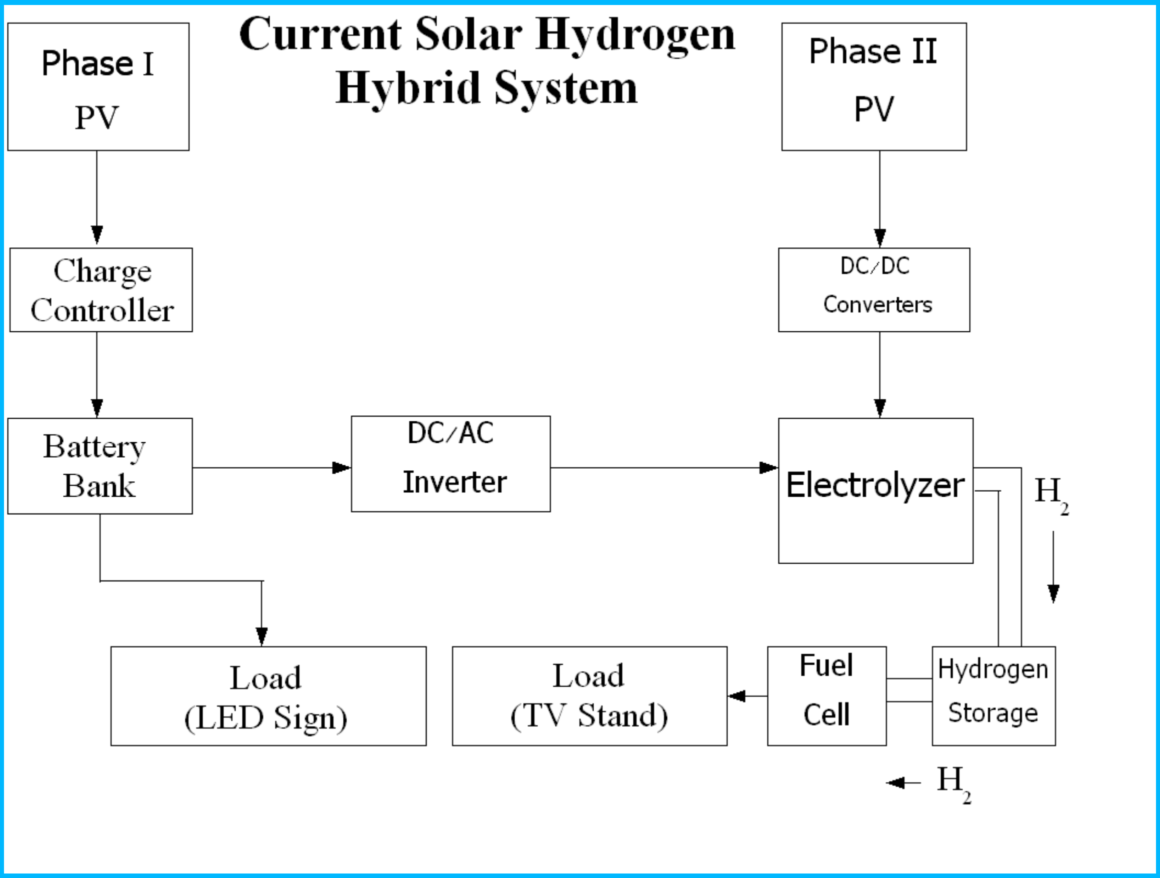
Introduction:

History

Eight years ago, a group of students lead by their faculty advisor began a project to investigate the use of solar energy to power an electric sign. Two phases were envisioned. The first phase involved powering an LED sign from batteries charged by solar energy and the second phase involved using power from an electrolyzer and hydrogen fuel cell as an energy back up system. The efforts of the original group, along with those of subsequent semesters, culminated this fall in the final push to run the sign from clean energy. The length of this project can be attributed to the amount of work and money that has been necessary to build the system.



Current Status

Figure 1: Diagram of Solar Hydrogen Hybrid System

Currently in Phase I, a photovoltaic array composed of multi-crystalline, mono-crystalline and amorphous silicon solar panels charges the bank of batteries to keep their total voltage output in the range of 44 to 60 volts. This voltage is sufficient to run the sign LED's. This transfer occurred last semester, but the sign was not operational before the summer vacation. These students also hoped to integrate the battery/solar panel and fuel/cell electrolyzer LabVIEW systems, but moving the sign to the roof presented more problems than expected and time ran out before this was completed. The sign itself was also intended to be monitored by web-cam.

Phase II involves using hydrogen to store solar energy. This phase would use the other set of solar panels to power the electrolyzer to produce hydrogen, which would then be used at a later time in the fuel cell to produce power to run the sign. The original intent was to even develop a controller to switch the system from battery power to hydrogen power. This was desired in order to provide continuous power from stored energy when the solar panels would not be effective, for example, at night or during cloudy streaks. Due to the technical details and complexity of these goals, they have not been accomplished. However, preliminary work with a fuel cell/electrolyzer system is being done alongside the battery/solar panel system. This work involves using the fuel cell/electrolyzer to power a TV/VCR combination and a smaller LED sign. The electronic equipment and the fuel cell are mounted on a portable stand, with a small hydrogen cylinder in order to demonstate these technologies at the workspace in the Co-Generation Plant.

Fall 2004 IPRO

At the beginning of the semester, the IPRO team decided that our goal would be to get the sign to work. The group made vague goals at this point because we did not know what we needed to do in order to get the sign to function. We could not have made specific goals at this point.

Documentation was poor and disorganized, so we spent the first few weeks poring over the documentation collected over the past several semesters. We decided that we needed to sort the documentation so that we would have a better picture of the history of the project. The most time consuming part of this sorting process was determining what information pertains to the current project or which documentation is out of date and useless. This problem was compounded by the fact that we did not initially know where all the documentation was. We later discovered documentation at a file cabinet at the project sight. We found that even after this, it was difficult to determine what needed to be done.

We then broke into smaller groups that would focus on separate aspects of the project and re-distributed the sorted documentation amongst the groups for further review. The following three groups were created: the sign group, which handled phase I of the project; the electrolyzer group, which worked on phase II of the project; and the data acquisition (DAQ) group, which handled the DAQ systems for both phase I and phase II. The responsibilities of and accomplishments of each group follows.

The Sign Group:

The sign team was responsible for testing the sign to ensure proper operation. The sign itself is an array of LED's assembled on a steel frame and mounted on the roof of the Co-Gen plant. It is connected to a microcontroller which is programmed by a computer to display various graphical messages. The sign has two inputs, one being a power cable and the other a cable connecting it to a PC.

Previous IPRO teams reported difficulty with connecting the sign to the computer. This would the biggest issue we would need to overcome. Initially we thought this would be a simple matter of just flipping switches on the main control panel and connecting the sign to the computer. However it turned out not to be that simple.

The first issue we encountered was that the previous IRPO team had not put the appropriate male DB9 connector on the end of the serial cable connecting the sign controller to the computer. We couldn't test the sign until we connected one. After locating a connector and attaching it, we had another problem. We were still unsure on what switches on the main control panel supplied power to the sign as the documentation was vague on this. We decided to test several switches until we found the right one, but it would be difficult to ascertain this as the sign was not visible from the control room. We tried to get the camera on the roof working for sign debugging purposes. The camera system software was having trouble on the existing computer so a laptop had to be brought in to test it. Eventually we got it working with the cameras in the control room, but we were still unable to get the camera on the roof to work.

The computer software reported errors connecting to the sign for every switch we tried, so we concluded that there was a power problem. After looking through some correspondences between the sign manufactures and a previous IPRO team, we noticed that the sign may have been modified and now required both 12 VDC for the LED's and 110 VAC for the controller and auxiliaries. The 12 VDC and 110 VAC however, were supposed to be provided by the batteries. But since they were completely dead, an alternative needed to be found.

We then decided to borrow a DC power supply. However one proved difficult to obtain. In the mean time we decided that we could try using the solar cells on the roof to provide power. After testing the power cables from the solar cells on the roof, we found we were getting no voltage.

The multitude of problems we were having and our lack of experience with the system required some external assistance. We decided to contact Brian Kustwin, who had previously worked with the system, for help. Brian charged the batteries with a small voltage over the course of a week to bring them back to their operational voltage. At the end of that week, we met to work on the system. Three main issues were addressed during the work day: the batteries were serviced, the system was explained, and the connection from the computer to the sign was reworked.

The batteries require an electrolyte to provide ions and water for the chemical reaction that produces power. Typically, the electrolyte does not need to be replaced, but the level was getting low in the batteries. Therefore, Brian suggested adding de-ionized water to ensure the batteries would not run dry. This task, as well as measuring individual battery voltages, was the first activity during the work day. A graph of the voltages can be seen in Figure 1. The majority of the cells charged to the proper levels, but there were a few cells that are below their full voltages even after a week of charging.

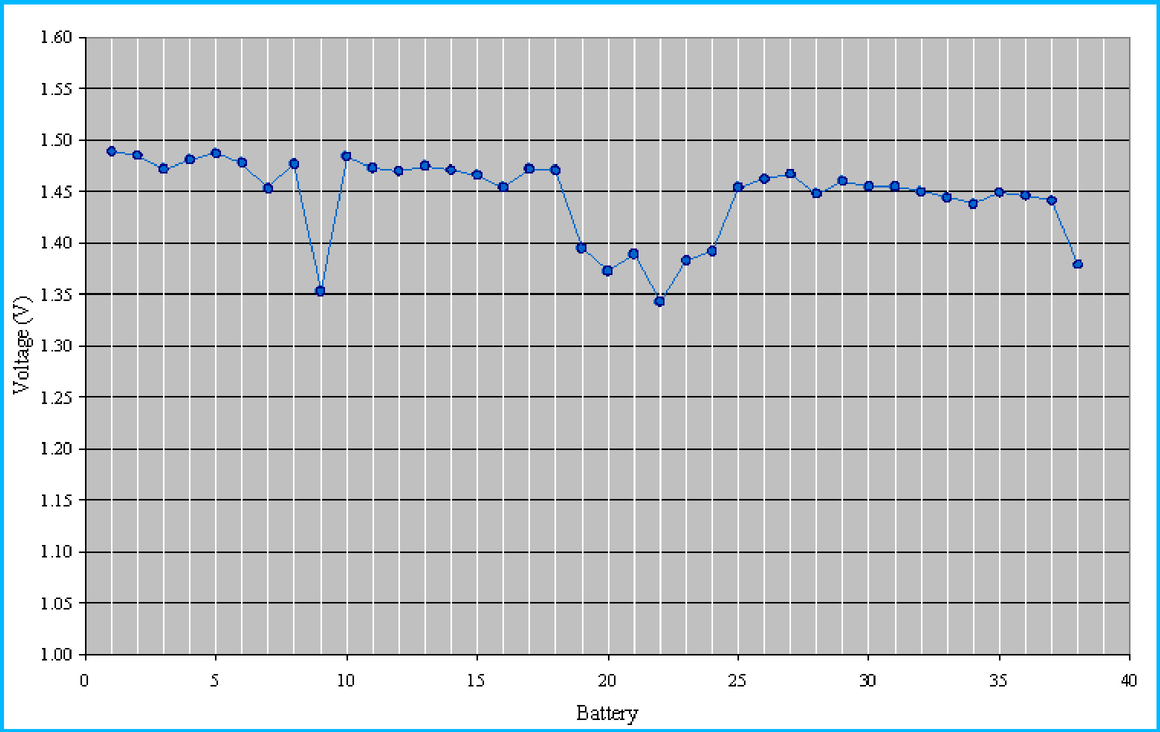


Figure 2: Battery voltage after a week of charging.

During the work day, Brian explained the system in more concise terms than could be gleaned from documentation. The switchboard in the control room has two parts, corresponding to the phases of the project. The bottom portion of the board was intended to connect the second set of solar panels to the electrolyzer in order to provide power to produce hydrogen for the fuel cell. The top portion of the board connects the first set of solar panels to the battery bank and routes the battery power to the sign on the roof. However, the controller connecting the solar panels to the rest of the system requires a load, in this case from the batteries, to draw any voltage from the panels. With the batteries completely discharged, the required load was not available, hence the previous problem of not measuring any voltage from the solar panels. Once the batteries were charged, this was no longer a problem.

The third concern of the work day was the connection between the computer and the sign. When the sign was installed on the roof, the plug of the cord coming from the sign to connect it to the controller was cut off to allow running it through the conduit. Earlier in the semester, we had attached a plug to the cord and connected the sign directly to the computer. Brian was able to correct this mistake during the work day. The cord from the roof needed a plug that would connect it to the controller box. The black box takes the information entered into the EDT software, converts it into a format the sign can recognize, and tells the sign which LED's should light up to display the desired message. From this box another cord runs to the computer. The end of the work day was spent attaching metal pins to the twenty-five wires in the cut cord. Unfortunately, we could not find any documentation that said what order the pinned wires should be installed in the plug.

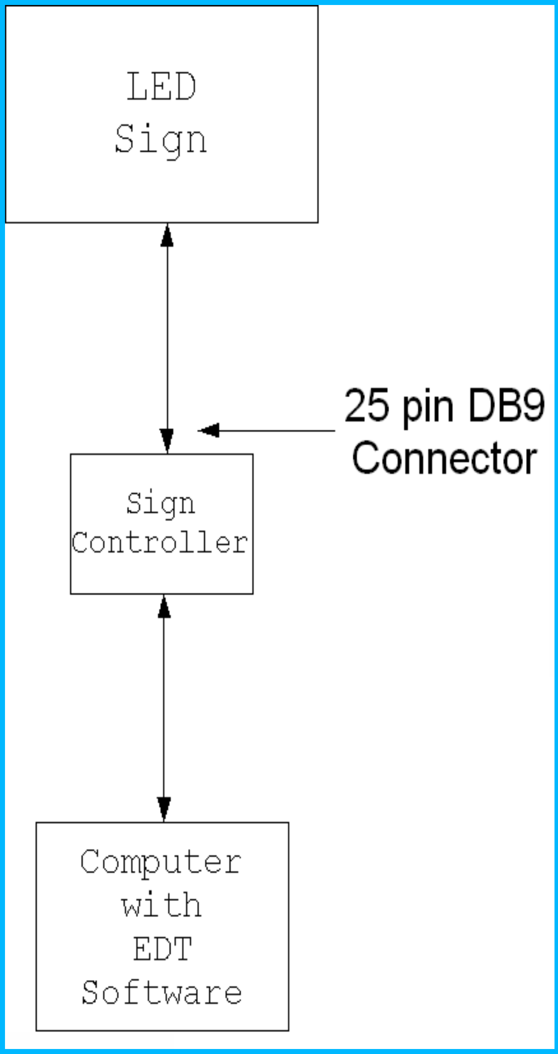


Figure 3: Diagram of computer to sign connection.

Brian said he had a cable that had connected the sign to the controller when the sign was from earlier in the project. After tracking down and locating this cable a few days later, we were finally able to attach the sign to the controller and the controller to the computer. A message was programmed, and the software was able to communicate with the sign. The sign even lit up; however, it did not display the programmed message. The companies that made the sign and the software have both been sold or gone out of business since the equipment was purchased, and so cannot offer any technical support. Technically, the sign works, in that it receives communication from the computer and displays data. The data it displays, however, is not the desired data.

Fuel Cell Group:

The initial goal for the fuel cell electrolyzer team was to get the fuel cell and electrolyzer working. We first familiarized ourselves with the equipment by reading the documentation left by previous IPRO teams, specifically the operation manuals for the fuel cell and electrolyzer.

When we first visited the Co-Gen facility we tried to turn on the electrolyzer and it displayed a flashing 4 error code. We consulted the operations manual which told us that there was not a sufficient pressure difference between the inside of the electrolyzer and atmospheric pressure. This is a safety feature to ensure that if any hydrogen is leaking into the electrolyzer, it will be purged out the rear exhaust vent and will not get near any live circuits. There is a fan that blows air into the electrolyzer in order to achieve this pressure difference.

We first tried to fix this error by removing the covers on the electrolyzer and inspecting the rubber seals. They seemed to be well attached and free of cracks. We then put caulk on some of the seals and replaced the covers. While replacing the covers we found that some of the screws were missing and we put duct tape over the holes. This was still not sufficient so we then put duct tape around all the seals for the covers. This was also not sufficient. We then taped over the exhaust vent. This was successful in achieving the necessary pressure difference, but it also negated the safety feature by preventing the purging of hydrogen.

With the vent taped over we could still not get the electrolyzer to produce hydrogen. Then we found a pump mounted to the bottom of a desk that delivered deionized water to the electrolyzer. Once we plugged that in the electrolyzer began producing hydrogen at 200 psi.

Now it was necessary to find a way to get the electrolyzer to work without compromising the safety feature of the hydrogen purge. We found that if we only taped over half of the exhaust vent, there was still a great enough pressure difference to start the electrolyzer. With this configuration we could operate the electrolyzer safely.

After we got the electrolyzer working we tried turning on the fuel cell. A green light on the power switch began flashing, but after consulting the operations manual we found that this just meant that internal controllers were functioning. The fuel cell contains 8 AA batteries that run its internal controllers, and it was still not producing a current. We thought that perhaps the cell was dried out and just needed to be run for a while to rehydrate the cell. We tried hooking it up to an external load for an extended period of time, but the cell would still not produce any voltage. We then opened the fuel cell and replaced some dead batteries. We also found that the connections that fed power out of the fuel cell were damaged, so we moved them up to another set of connections in better condition. After that we were able to get the fuel cell to deliver power to the television and the led sign on the fuel cell stand.

In the future, it would be advantageous if the four way valve that currently connects the fuel cell, the electrolyzer and the hydrogen tanks, were replaced with a manifold. This would eliminate the need for someone to manually turn the valve, in order to draw hydrogen from the other tank if the first went empty. For now, though, the four way valve is still more practical, because it allows one tank to be run continuously from full to empty, without drawing any hydrogen from the other tank. This would allow future teams to test how long the fuel cell can be run on one tank, how much power can be produced from one tank and so on.

DAQ Group:

The DAQ team can be considered more of a backup group for the other two teams. While this semester's work wasn't as substantial as we would have hoped, we still feel that a great deal of progress had been made.

We started the semester with little to no knowledge of the LABView, popular data acquisition software, or any other crucial part of this project. We spent the first few weeks poring over the documentation collected over the past several semesters.

Reading the documentation however was only half the battle to understanding the system. The first day we went to the project site, we spent the whole time working with the Sign Team and the Hydrogen Team. The Hydrogen team needed to take measurements on the voltage produced by the fuel cell. The Sign Team needed various voltage measurements on the voltage coming in from the panels to the voltage of the battery bank.

The Hydrogen System:

The DAQ group helped with the following:

- Take voltage measurements across the output terminals of the fuel cell.
- Take voltage measurements across the input/output terminals of the inverter.
- Use the LABView software to measure the pressure of the hydrogen produced by the hydrogen generator.

The main obstacles in working with the Hydrogen Team was to wait for them while they troubleshot the hydrogen generating unit in order to have it maintain a steady flow of hydrogen to the tanks. Another problem was trying to figure out how the LABView files were set up on the computer connected to the fuel cell. We were getting readings that were completely off.

The Solar Panels/Sign:

It is important to note here that there are six shunts in the system. Below is a listing of each shunt:

1. Channel 1 (**V1**): System Voltage in Volts.
2. Channel 2 (**V~I1**): PV1 (MSX array) Current
3. Channel 3 (**V~I2**): PV2 (Millennia array) Current
4. Channel 4 (**V~I3**): Load (Sign) Current
5. Channel 5 (**V~I4**): Battery Current
6. Channel 6 (**Vpr**): Pyranometer Voltage

Note: These shunts are connected to the Keithly multimeter unit which is connected to the computer running LABView. Shown below is a pseudo-schematic of the solar panel/sign system (Phase1).

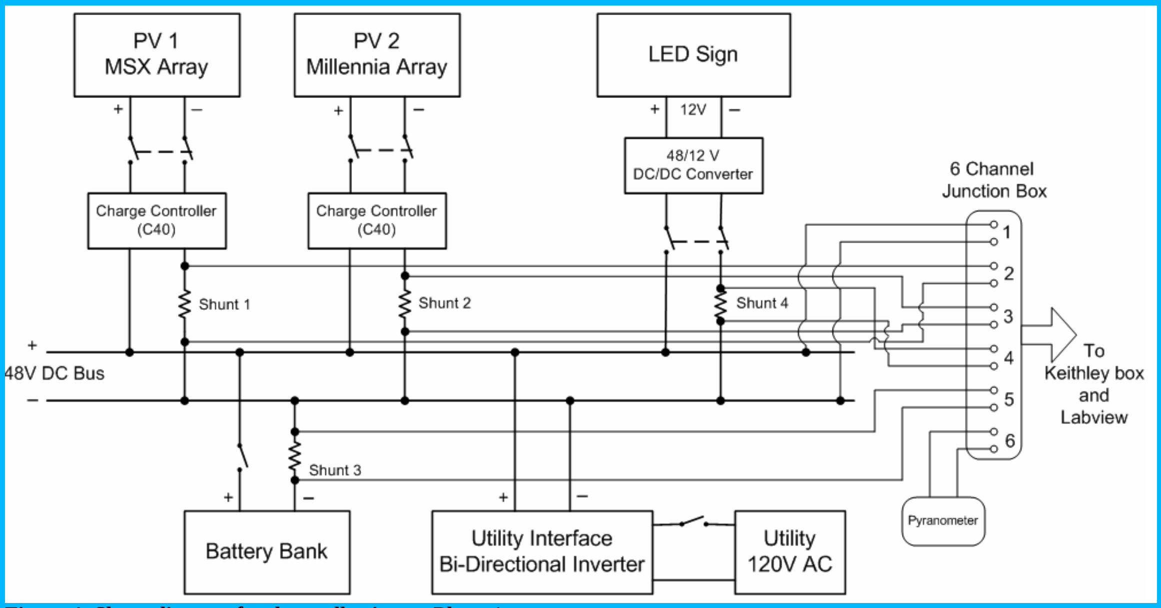


Figure 4: Shunt diagram for data collection on Phase 1

Shunts are small metal bars (of known resistance), in parallel with a potential difference. These shunts allow the data acquisition equipment to measure voltages at these respective points.

.Once the sign can be connected to the computer, we can begin taking data measurements of the running system. Because once the sign turns on, it will act as the load for the system and meaningful data can be gathered. Until this time, it will be difficult to verify if the DAQ system is working.

Website:

Another one of the DAQ team's responsibilities is to update the website. The website has information from the fall of 2003. We had planned to update some of the graphics and some of the graphs. The structure and layout of the website is pretty easy to navigate through. There is no reason to modify this. Shown below is the site map:

Home: A brief introduction to the project
Project Management: A description of the faculty members in charge of this IPRO
Project Summary: A simple summary of the project
Project Description: An in-depth analysis of the entire system with some schematics
Project Sponsors: A listing of the corporate sponsors of the project
Pictures: Pictures of the worksite and the Fall 03 group
Accomplishments: A list of links to presentations of previous groups
Conferences: A listing of energy related conferences
Project Team: A listing of the Fall 03 team members
Live Camera: Some pictures taken with the webcams
Related Links: Links to some sources related to the project
Contact Us: Contact information

Sign For Our Time: A link to the IIT Contact Newsletter
Annual Report Solar Power: A link to some information about the project on the CHEE department website
Renewable Energy Workshop: A link to the Renewable Energy Workshop held last year at IIT

This format should stay mostly the same way it is, just change some of the links and hopefully we'll have some data measurements to post.

Internet Connectivity:

One of the other things we worked on was connecting the computer by the controller board to the network. For some reason, it had lost it's connectivity over the course of the summer. We disconnected the wire-less receiver from the switch and plugged it into the computer directly. Then we configured the network settings to DHCP (in order to automatically obtain a dynamic IP address). However, since that computer will be used as host for uploading webcam images to the website, we needed to obtain a static IP address from OTS (Office of Technology Services).

Wireless Webcams:

We also worked on setting up the wireless camera system. There are 4 cameras on this system; two on the roof and two in the workspace. The two on the roof need to be checked for power connectivity and the wireless receiver doesn't work with the computer near the control panel. We tested the receiver with a laptop and had no problems. We think that if the unit were to be moved to the other computer (by the hydrogen generator) and the necessary software re-installed, then it should run with no problems.

We recommend replacing the current webcams for something a little more reliable, especially the ones on the roof. The cameras may not be able to handle the weather conditions. This may be another reason why we're not receiving any signal from the cameras on the roof.

Conclusion:

To summarize, this semester we have achieved our goal of powering the LED sign. The fuel cell/electrolyzer system also works, though intermittently. Through setbacks including poor documentation of previous work which affected the EDT software connection and data acquisition system, a slow start and lack of direction at the beginning of the semester, and difficulties accessing the system due to its location, we have learned some key lessons. One such lesson is how to work as a team to accomplish what we could, when we could. Another is that communication with bosses or supervisors is necessary for a successful project. For example, if we do not know what is going on, we should ask someone who does for clarification. One suggestion for future semesters is to get a better start on the project. One of the first two meetings should be spent in discussing the history and overall goal and direction of the project. It would also be helpful if the preceding group leaves recommendations concerning where the next group should start and what direction the project needs to go.