# Hybrid Wind Solar Generator

*Design Document*

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# Contents

# 1 Introduction

## 1.1 Project statement

The development of a hybrid wind and solar power generation system.

## 1.2 Purpose

As “Green” energy is a growing industry, implications are developing on the supporting architecture of the power grid. Building this hybrid power generation device will allow us to test the role renewable energy will have on peak loads and the necessary supporting architecture.

## 1.3 Goals

- Design the hybrid system using software simulation in order to better understand its inner workings.
- Purchase and set up a wind turbine.
- Combine the newly purchased wind turbine and the already existing solar panels so that their generated powers combine together.
- Create labs for EE 452 centered around the hybrid system so future ISU students can use the hybrid system as a learning tool.
- WESO

## 2 Deliverables

To complete the goals listed above, we will need to understand how wind and solar energy systems work on a component level, as well as on a simulation level. Each team will need to do research on their respective topic and build a simulation model that accurately reflects what the system should accomplish.

Specifically, Solar team will need to study and verify the photovoltaic effects through varying temperature and irradiance on the system, as well as by studying the effects of the absence and presence of the maximum power point tracking, a battery bank, and finally a load. From there, we will move onto the hardware component of the project in order to verify our results and gain an overall understanding of how the system works in everyday weather conditions.

Wind team will need to develop a similar model that can monitor the output of a system with changing variables. How these variables affect the output include wind speed, rotor area, and power coefficient. Once we implement the hardware, we will need to make sure to include equipment to monitor wind speed, voltage, and power flow so we can compare our system to the simulation.

Once both the wind and solar components are working individually, we will then combine them in simulation and then, based on the simulation, combine the hardware. We will need to verify that the systems are working together and then develop reproducible lab experiments to be used in EE 452.

# 3 Design

To solve the problem of creating a stand-alone, hybrid solar/wind power generation station there are multiple design considerations. Separate systems for solar generation and wind generation will need to be designed and tested then combined into a finalized hybrid system. Developing the software models requires research on how to implement solar arrays and wind turbines and what other parts would be needed outside of the arrays and turbine themselves. From here, the team learned that our final solution will require solar PV arrays, a device for Maximum Power Point Tracking (MPPT), battery storage, boost converter, an electrical inverter, and simulated load. So far, all of these devices have been modeled in software and testing has begun.

Each component will be built and tested individually before being combined with the other devices. This will allow for better quality control and be easier to find bugs before the final design. The testing process entails taking the finished device (modeled in software) and creating inputs that will generate known results. If the results match, the device can be implemented into the project, where the same testing procedure will be utilized. For example, our group has created a inverter in code to simulate the hardware inverter that we currently have available. This device is designed to convert DC electricity to AC electricity and in order to test the individual device DC voltage was inputted and AC voltage was observed at the output. Once this was placed into our larger project we tested the entire project to verify our results. This iterative process will be repeated until all of our devices are modeled, tested, implemented and verified.

Hardware related to the solar system has already been purchased by a previous Senior Design group and will be re-used for the current iteration of this project to keep costs low. However, the implementation of the system devices may vary once the current hardware is combined with the hardware for a wind turbine. A wind turbine and related supporting systems will need to be purchased at a later date.

## 3.1 System specifications

Solar team has been given and will use two Kyocera Model KD135GX-LPU solar panels, an MPPT to allow for maximum power to be output from the system, two 12V, 90Ah high capacity lead-acid batteries for power storage, a Samlex PST-600-24 Pure Sine Wave Inverter for voltage conversion (24V DC to 120V 60Hz AC), and a resistive load consisting of four light bulbs. All simulation work will be done on Simulink.

Wind team is in the process of purchasing a wind turbine and generator but has already received and will use a three phase rectifier, filter circuit, boost converter, two 12V, 90Ah high capacity lead-acid batteries for power storage, a Samlex PST-600-24 Pure Sine Wave Inverter for voltage conversion (24V DC to 120V 60Hz AC), and a resistive load consisting of four light bulbs. All simulation work will be done on Simulink.

### 3.1.1 Non-functional

The most problematic non-functional requirement pertains to obtaining permission to mounting a wind turbine in either Coover's courtyard or the northwest corner of Coover. Doing so will require

Coover administration to verify the wind turbine is structurally sound and that its installation has been done correctly. If we choose to place the wind turbine in the northwest corner, we will have even more non-functional requirements in that we have to worry about aesthetics which would require bringing in an ISU architect. The architect's job would be to ensure the wind turbine fits in with the campus's aesthetic.

Our second non-functional requirement is obtaining the funds to purchase the wind turbine and to properly install it. We believe this is possible, but it's highly unlikely that we will have funds to purchase the type of turbine we would like. We would like a vertical axis wind turbine which has sensors so we could observe the turbine's inner workings during operation.

### 3.1.2 Functional

Electrical Energy from the wind and MPPT solar systems is stored in batteries and used with a variable resistive load that reflects peak and non-peak times.

## 3.2 PROPOSED DESIGN/METHOD

Simulations will be done first alongside the wind turbine's research and placement. An iterative process as discussed earlier will be used to test the simulations and hardware for functionality and performance. Then the team will start working on the supporting hardware, and perhaps start attaining readings during different environmental conditions. From the software simulations, hardware devices will be purchased and implemented. Using gathered data from these hardware devices we will be able to verify how well our system is working and fine tune any portions of the project as needed. Lastly, we will need to present our findings to our advisor.

## 3.3 DESIGN ANALYSIS

So far, solar team has been modeling the solar array setup in simulink to develop a better understanding of what the system is supposed to do. In this process, we have broken the system down and have run simulations with and without certain components to see what the outputs we would get under certain conditions. Specifically, we have simulated the solar array with and without the maximum power point tracking, as well as with and without a battery and load attached to verify that the outputs we were getting were accurate to what we would expect the physical system to produce. We then put the whole system together to monitor voltage and current outputs at each stage of the solar array and have found inconsistencies that are currently being worked out. To move past this stage, we are trying to break down the system into even smaller pieces to find out exactly where the outputs have gone wrong, and will debug from there.

The wind team has been researching wind turbines that can potentially be used in the courtyard or outside of Coover hall. In conjunction with research we have contacted the building manager and discussed our options and the approval needed to place a wind turbine in Coover. In order to determine the best location and the viability of placing a turbine near Coover we have acquired an anemometer on a thirteen foot pole that we can record data with to measure the wind speeds in different areas over a twelve hour period. Without enough constant wind we will not receive any power from our system so we will need to determine if we have a viable location before we purchase a wind turbine. We are also working to develop a Simulink model of our wind turbine and how the systems after the wind turbine change the power received into the correct output for our system.

# 4 Testing/Development

## 4.1 INTERFACE specifications

In order to better understand the stand-alone hybrid system, software and hardware systems were created separately. Within the software model the entire system is to be build with MatLab Simulink including devices to measure the outputs of the model. This entire modeling process does not involve any hardware but will be directly transferable to the hardware system. The hardware system is required to interface with various software components for measuring and verification. Once the hardware system is built, measurements for voltage, current and power will be performed via LabVIEW and National Instruments sensors. The National Instruments sensors will interface directly with National Instruments Data Acquisition Software (DAQ) on a designated computer terminal used for the project. Using the DAQ software, the Maximum Power Point Tracking (MPPT) system will use the Perturb and Observe Algorithm that comes pre-programmed into the MPPT. The Perturb and Observe Algorithm will be a software program designed to control maximum power efficiency but will not need to be developed by the students. Other software and hardware interfacing may be required and will be decided at the discretion of the advisor and students.

## 4.2 Hardware/software

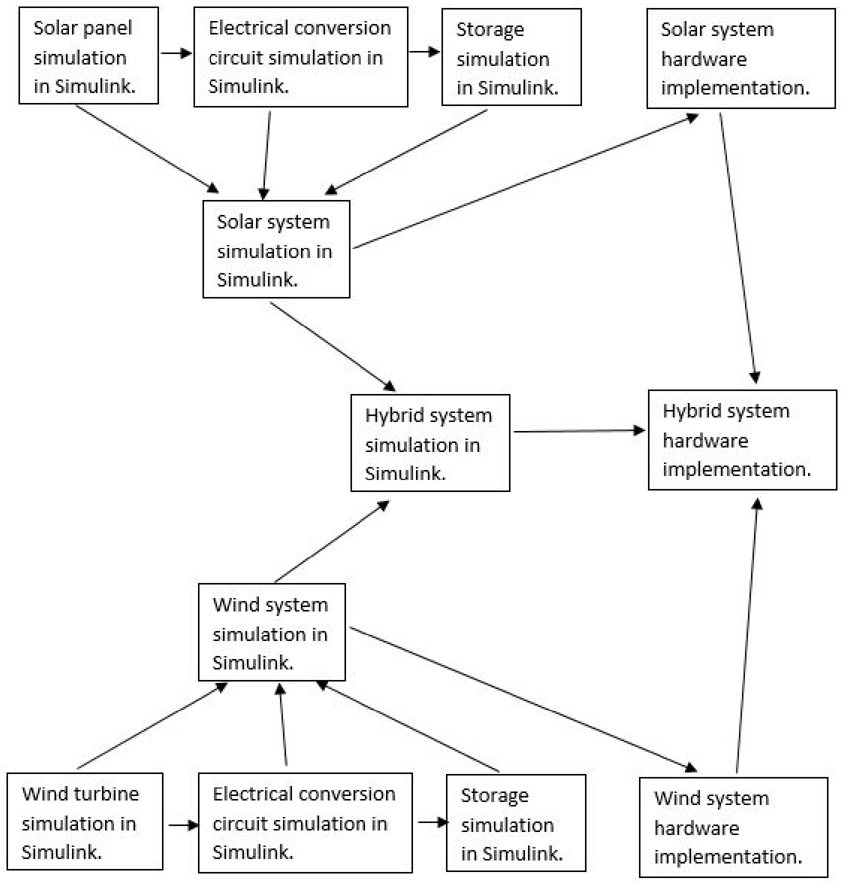
Before implementing the hardware, we will be implementing and developing our system with Matlab Simulink to make sure that our system is modeled properly and that we don't run into any problems once we start working with the hardware. We will create an individual model for both solar and wind and then combine the two into a hybrid system.

Our solar system will use two photovoltaic arrays to generate power. Along with the panels will be a battery system to provide power when there is not enough power produced by the panels and to store power when there is excess energy. A maximum power point tracking system will be used to maximize the output power of the panels. An inverter will be used to convert the DC voltage to 60 Hz AC voltage. Our system will be connected to a resistive load consisting of several light bulbs.

Our wind system will consist of a vertical axis turbine, a rectifier, and a boost converter. The wind turbine will generate power for the system. Since it is a vertical axis turbine, it takes in wind from all directions and the wind direction and orientation of turbine placement will not be a factor in power generation. The rectifier will convert AC voltage to DC voltage and the boost converter will step up the voltage to 24 V DC and will be fed into the batteries and inverter of the solar system.

## 4.2 Process

Please see the diagram below for more details.



# 5 Results

The simulations have been difficult because not many of our members are experienced with using Simulink. There have been multiple attempts to obtain accurate results from the simulations but so far some of the data is not correct. The system works but does not output correct numbers so more testing must be performed to resolve these issues.

It seems that the courtyard in coover can have a wind turbine. The wind measured shows that wind direction changes frequently and more data is required to learn more about the conditions here.

Due to the fact that we are still developing simulations, we haven't gained simulation data that would effectively show a nominal result of environmental conditions. When simulation results are finalized, we will compare with the readings gained from the hardware during operation.

# 6 Conclusions

In conclusion, after completion of our project according to the aforementioned plan, our Senior Design Team will have created a simulated wind turbine, simulated solar array, a simulated hybrid (wind and solar) system and physical hybrid system that will be able to operate completely off-grid. In addition to the power generating components of the wind turbine and solar panels, our design will also include a system to ensure maximum power efficiency (Maximum Power Point Tracking system), a system to store unused power and a system to simulate a load or a demand for power. Once the system has been implemented lesson plans will need to be developed so that the hybrid generation station can be included as part of the course curriculum for EE 452.

Some of our other short term goals include working with the Wind Energy Student Organization (WESO) to potentially provide funding for our wind turbine and long-term support even after our group has graduated. Coordination with Facilities Planning & Management is also necessary in order to mount a wind turbine in the Coover courtyard or on the roof. The process to achieve our goals is already underway and our team is making sound progress to finish our project.

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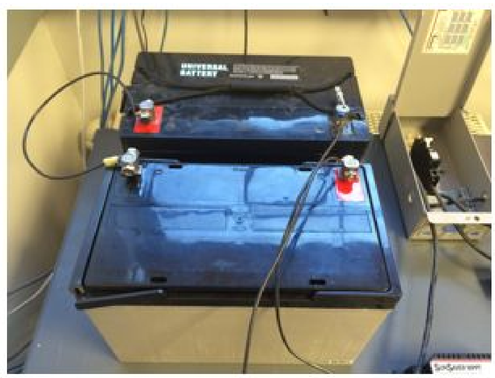
# 8 Appendices

Solar panels

Panel combiner


MPPT



Batteries

*Both systems will ultimately share the same Batteries, Inverter, and Load.*