

Design and Implementation of a Small-scale, Standalone Hybrid Solar PV and Wind Energy System

DESIGN DOCUMENT

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1 Introduction

1.1 ACKNOWLEDGEMENT

Professor Venakataramana Ajjarapu has overseen and given assistance to this group, primarily in the form technical advice and equipment. He has given us the necessary resources to learn what background material we will need regarding the solar panel power generation process. He has also provided us access to the EE 452 lab and all its equipment pertaining to our project.

1.2 PROBLEM AND PROJECT STATEMENT

The objective of this project is to improve upon and design a new element for the EE452 lab regarding solar panel power generation. The goal of this lab is to allow students to gain hands on experience working with the Photovoltaic (PV) array and how it is used to generate maximum power under changing weather conditions. Our solution is to maintain the general framework of the lab, while implementing a new, more realistic load. This load will simulate a small-scale house and demonstrate to the users how solar power can be used to power a home, as well as what might be some common issues encountered when trying to implement a solar panel on a house.

1.3 OPERATIONAL ENVIRONMENT

While the PV arrays remain outside to generate sufficient solar power, our small-scale house load will remain inside the lab room. It will be exposed to dusty conditions, but will not be exposed to any extreme weather. It will always operate under near room temperature and will not be subjected to any precipitation of any sort.

1.4 INTENDED USERS AND USES

Our project is focused around improving and developing on the labs for EE 452. Or design will be used by students who are trying to learn a basic understanding of solar generations and its capabilities. The uses of our design will be to help the students see a load model that could be compared to a real-life home. It will show the different elements of loads that would be seen on a grid: capacitive, inductive, and resistive. It also allows for the students to model the power requirements of what would need to be supplied by the solar panel and the battery that are in the system.

1.5 ASSUMPTIONS AND LIMITATIONS

Assumptions:

This is something that will be used only as model. It will function at a steady voltage supply and will be regulated for the safety of the circuitry. This is intended to be used for only one user/group at a time, but this can be modified if need be. This load will be stationary and is not made for frequent movement.

Limitations:

This must work off of the already provided PV generation. It must be able to fit in the establish space for different load models in the EE 452 lab. There must be accessible circuit components that are able to be replace as needed. The cost has not been defined at this point.

1.6 EXPECTED END PRODUCT AND DELIVERABLES

The end product that we will work on next semester is providing a model home that represents various capacitive, inductive and resistive loads. It will have protected circuitry that can be accessed when components fail. It will be a model that represents a home and the independent loads it intends to represent. For example, it will look like a house and there could be scaled lights as resistors, electric motors for inductors, and batteries as capacitors. We will add a defined I/O that will be compatible with the generation system available. It will also have modeling and test results showing how this load works in the defined system, and it will be applied into the existing PV labs and show how it is possible to power a home with this type of generation. This will come with instructions that will be used in lab documents, on how to connect this load to the generation and potential checks if there are problems. The final product must be completed, tested, documented, and put in place by the end of the 2018 fall semester.

2 Specifications and Analysis

2.1 PROPOSED DESIGN

The proposed design consists of multiple components, each playing a key role in the objective. A PV array will be connected to an MPPT. This MPPT will allow for the PV array to generate maximum power at all times. It does this iteratively by constantly changing the load seen by the PV array to get maximum power output. The ideal load for maximum power output depends upon irradiance and temperature, both of which vary each second. These characteristics are show in appendix figures A.1 and A.2. A buck/boost converter will be used in the circuit in order to change the voltage to whatever the load needs. It will Power our one of three loads as well as a battery for charging. The battery will be used to power the loads during times when the PV array is not capable of doing it on its own.

This has been tested in Simulink, and the increase in efficiency and consistency that this design provides is significant. Updates to our design will be done first by simulation in Simulink. Then, our change can be slowly implemented into our physical system.

2.2 DESIGN ANALYSIS

Various components of our design as well as interactions between them has been thoroughly investigated using Simulink. The simulation of our entire system has not been successful, as parameters need to be changed, and components need to be implemented. However, results still showed a great increase in efficiency and consistency of our proposed design of the simpler design. The MPPT is responsible for greater power efficiency, which leads to few power losses. Also, the battery allows for 24-hour consistency, approximately 3 times as often as a simple system. Weaknesses are few and relate only to the complexity of the circuit. More components and variables mean that one thing going wrong will ruin the entire system. It also means that the system will be reasonably more difficult to debug and fix.

2 Testing and Implementation

Tests will be needed to approximate mostly one variable, power, over time. While looking at certain voltages or currents will help understand a problem, if the power output is consistent and efficient, nothing else is really necessary. Simulink will be used to simulate this on the software side.

2.1 INTERFACE SPECIFICATIONS

Simulink will be the main program used to model our project on the software side to see if a hardware result is feasible. We have an accurate representation of the entire circuit created in Simulink with all the various components. When adding new components or changing variables, we can first change them in Simulink to simulate how the system will react before adding them to the physical setup. This will allow us to have safer, more reliable improvements to the system.

2.2 HARDWARE AND SOFTWARE

The hardware that is being used is the current setup that includes different loads such as DC Train, single phase light bulb setup, 3-phase motor, with heavy emphases on the model home load. The loads will allow students to understand how power flow works in a small model home with different loads that represent appliances in the home. Students can then monitor the amount of power flow going through the system and where there are losses in the system. This is made possible through the Arduino control. The Arduino receives various data signal wires from the PV array, a thermometer, and pyranometer. Using a display library, it saves these values and plots the irradiance over time as a graph and displays current temperature. Students can also observe the amount of solar power being produced by the solar panels, and how it can be used in real life application of powering appliances in homes.

The Software that is being used is Simulink and MATLAB. Simulink is a function in MATLAB that allows the user to be able to simulate, model and analyze systems in a safe environment. Simulink will allow us to simulate the amount of voltage and current across each component of our home and be able to see the power consumption when each load is turned on as well as the amount of solar energy needed to power the home. We will use this to test certain loads within small home without the harming the current setup, testing it in a safe environment before building the final model. Figure 1 shows the current Simulink model that we used to test different resistive loads with a solar panel.

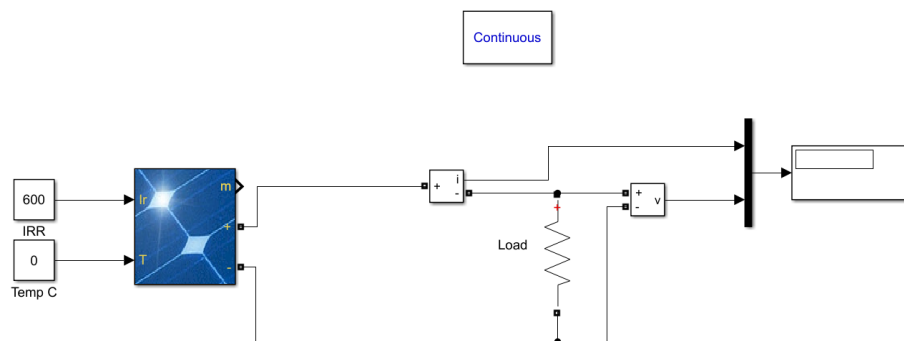


Figure 1: Resistive Load Simulink Model

Currently, there are multiple safety hazards present in the setup. These include, but are not limited to: exposed wires, exposed connections, easily accessible hot points, improper groundings, and unintentional moving parts. These are very serious and could cause significant harm to a person or equipment. We have already seen arcing, accidental groundings, and improper readings from the system from poor wiring. In our design, we will fix the wiring so accidental movement or grounding of wires does not happen, and we will block off the system to make it harder to access.

Parts needed for the improvements include various resistors from $1\ \Omega$ to $200\ \Omega$ with high enough power ratings to work with the PV array when giving maximum power, around 100W minimums. We need a breaker to keep the system safe, 2 additional solar panels for more power generation, 2 more batteries for additional capacity, and pile wood and plexiglass for safe storage. The total cost estimate is \$1,263.31.

2.3 FUNCTIONAL TESTING

In Simulink, the system will be tested by simulating a full day cycle of the power the home uses. For example, the home will have appliance such as scaled lights acting as resistors, batteries acting as capacitors, and motors acting as inductors. The Simulink design will include measurements of voltage and current going through each of these components. This will output an excel file that gives the details of each component. These details include the irradiance and temperature at certain times during the day and respective component values of voltage and current going through each. With these, we will be able to measure the amount of power flow through the system, how much power is lost going through each appliance, and effects of the battery when each load is turned on. Ideally, the solar panel will produce enough energy to be stored in the battery so the home can run during the night.

Various technical problems were encountered in creating the current designs that exist. One major problem is the location of the solar panel. It is currently located in a poor area where it has a shadow cast on it for around half of its generation potential time, depending upon the year. All ideas of moving the solar panels to the roof or attaching them to the side of buildings have been shut down due to school regulations and cost of installation. The previous setup had issues with circuitry in measuring correct values as well as safety issues that needed to be carefully adjusted.

2.4 NON-FUNCTIONAL TESTING

In addition to testing the following components under normal load, we will need to test the components under small amounts of energy produced from the solar panels. The amount of energy being produced by the solar panels varies daily, and changes with the amount of sunlight hitting it during the day. Therefore, the amount of energy being stored could be less than optimal. Thus, we must determine the smallest amount of energy to be able to run this lab. Since there are also multiple lab sections, we need to consider the minimum power stored to be able to run the lab multiple times during the day. When the design is setup, and it is determined that the lab cannot be run more than twice during a given day, then revisions will be made to the loads to use them during multiple labs. If the system can be run twice during the day at minimum amount of energy, then the system is feasible.

2.5 PROCESS

Simulink will be used initially to test all of our designs because we need to ensure the model works in the ideal case before we continue to prototype our design. Simulink has very well-defined models for most of the components we will use in our design, and for those that are not predefined, we will design our own models for use in Simulink.

To test our prototype small-scale house, we will first use a standard AC source without the solar panel to minimize variables. The next step will be to test the model home with a DC source connected to an inverter to produce the AC signal necessary for the load. Lastly, we will test the entire system together. The house is currently in the design phase. It will simply be various loads put in parallel and series that can be switched on and off.

2.6 RESULTS

We have simulated the various properties of the PV array, and we know what to expect from it. The loads are the only aspect we have yet to incorporate, as our model house is currently under design. Further testing is needed once the designing is completed for specific proposed models.

3 Closing Material

4.1 CONCLUSION

For this project, we have done the necessary amount of research of PV cells and MPPT's to move forward with our project of the model house and testing of the current state of the EE452 Lab. From the testing of the lab, we will work to improve the lab with understanding the work done to finish the lab and by including the element of the model house into the lab steps. Having done these will give students a better comprehension of the lab as well as an extra element to give students a better understanding of the model house load on a PV system.

We have carefully identified many problems with the current setup that we plan to fix. Some are functional, giving students inaccurate results and hindering their learning process. Others are safety related and cause serious dangers to anyone using the system. Our design will fix these safety issues, and it will enhance students' learning objectives through improvements.

4.2 REFERENCES

Our main references were the previous group's material, which included circuit setups, research articles, and presentations. In addition, we did additional research of PV arrays and various other aspects and potential design implementations.

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4.3 APPENDICES

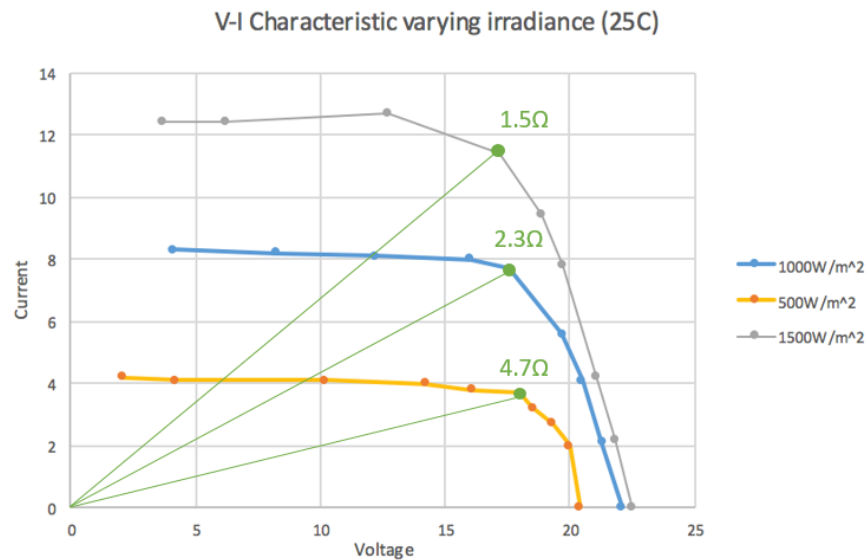


Figure A.1 - VI Characteristic Irradiance Graph

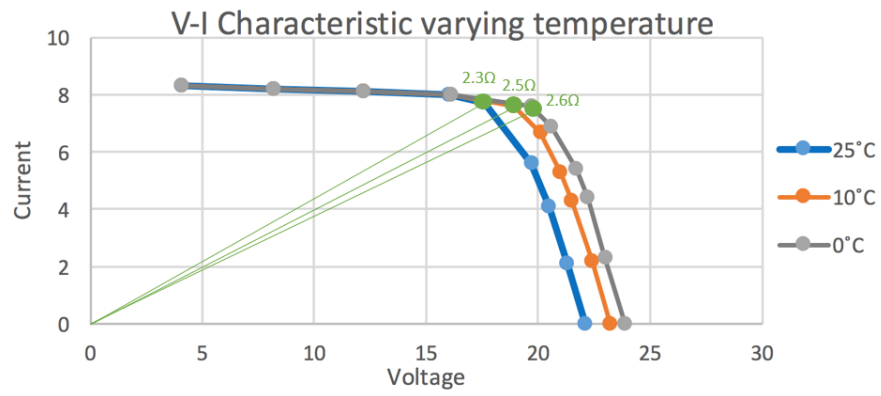


Figure A.2 - VI Characteristic Temperature Graph