Solar/Battery Power System

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**Functional System Requirements**

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Functional System Requirements

for

Solar/Battery Power System

Team <16>

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The following definitions differentiate between requirements and other statements.

Shall: This is the only verb used for the binding requirements.

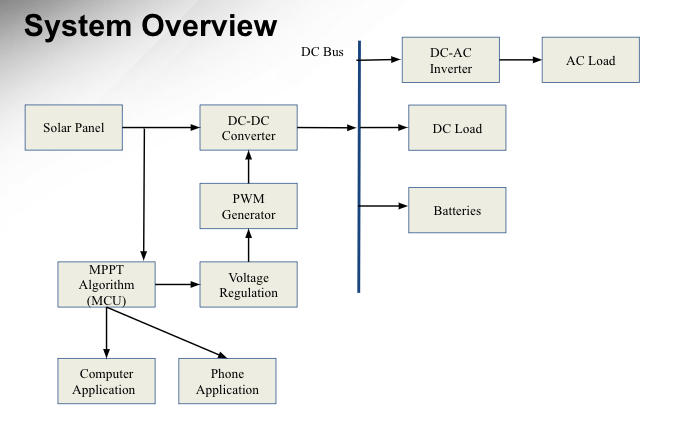
Should/May: These verbs are used for stating non-mandatory goals.

Will: This verb is used for stating facts or declaration of purpose.

# Introduction

## Purpose and Scope

The solar/power battery system is an accessible way to bring clean energy into homes. It can be used during power outages or for those living in rural areas. The design is to help those with basic knowledge of solar panels regulate and sustain their independent grid. The system will be able to charge common household electronics including laptops and phones. The user will be able to oversee the grid using an android phone application and a computer website. **Figure 1** below represents the system overview of the project in the proposed CONOPS document.



**Figure 1.** *Topology of Solar Power Battery System*

The system will be powered by solar power during the day, and then by a battery when the sun is no longer sufficiently providing energy. Current and voltage sensors will record the output of the solar panels, battery, and DC load. The Maximum Power Point Tracking (MPPT) will determine the optimal voltage and current to be set throughout the system based on the efficiency of the solar panel. All of the information collected will be transmitted through WiFi, which will then be uploaded to an online database. The system will display the trends and information of the day and present it on an android phone application and computer website.

## Responsibility and Change Authority

The team leader, Nathan Gil, has the responsibility of making sure that all requirements for the project are met. These requirements can only be changed through the approval of the team leader, and the approval of the sponsor Dr. Peng-Hao Huang.

| **Subsystem** | **Responsibility** |
| --- | --- |
| Microcontroller and MPPT | Lauren Lugo |
| DC to DC Converter | Tarik Dawson |
| DC to AC Inverter | Clement Ong |
| Phone and Computer Application | Nathan Gil |

**Table 1.** *Subsystem Leads*

# Applicable and Reference Documents

## Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| IEEE 307 | 1969 | IEEE Standard Definitions of Terms for Solar Cells |
| C2-2023 | 2023 | National Electrical Safety Code (R) |

## Reference Documents

The following documents are reference documents utilized in the development of this specification. These documents do not form a part of this specification and are not controlled by their reference herein.

| **Document Number** | **Revision/Release Date** | **Document Title** |
| --- | --- | --- |
| - | - | - |

## Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

# Requirements

When we refer to the “Microcontroller and MPPT system” we are referring to a subsystem that is composed of a microcontroller, PWM generator, and the MPPT algorithm. This subsystem is expected to accurately track the sun to harness the maximum power output. In doing so, the subsystem shall be able to determine if the solar panel should be in charging or discharging mode, the fluctuations in solar harnessing depending on implications to the solar panel line of view, and the current and voltage of the solar panel after harnessing power from the sun. This subsystem shall then be able to send this data to the website and android application through a backend database. The “website and android application” refers to the user interface that the user will see when trying to evaluate the solar powered system. This system shall be able to retrieve data from the database and display it for the user for their convenience and analysis. The website will be accessible for anyone from anywhere as long as it has been paired up with their specific solar powered system. The android app shall operate in a timely manner for android users and display the information provided under the **Block Diagram of System** section. The “DC to DC converter” shall be able to convert any voltage level that is outputted from the solar panel to 12V which can be used anywhere else in the system. This subsystem shall work accurately and accordingly to not harm a user's device. The “DC to AC inverter” is composed of an AC inverter and a PWM generator which shall alter the DC output of the solar panel into the appropriate AC signal needed for the AC output.

## System Definition

The solar/battery power system aims to provide a source of renewable energy, using solar energy to provide power to a laptop, cell phone, and various other consumer devices. The system will charge a battery while also providing an AC outlet as well as DC outlet to power any device connected to it. The solar/battery power system consists of 4 subsystems as shown in the figures below: Microcontroller and MPPT, DC-DC converter, DC-AC inverter, and the phone and computer application.



**Figure 2.** *Block Diagram of System*

The microcontroller/MPPT subsystem shall use current and voltage sensors to adjust the output of the various loads. The microcontroller shall be programmed to use Maximum Power Point Tracking (MPPT) to optimize the output to the loads. Specifically, utilizing the sensors to determine the proper Pulse Width Modulation (PWM) to send to the DC-DC subsystem. Additionally, the microcontroller shall determine if the battery is charged or should be charged and adjust the voltage/current supply accordingly. All data from the sensors shall be sent over wifi to the database used for the android application and website subsystem.

The DC-DC buck converter subsystem shall take the variable output voltage of the solar panel and convert it to a stable 12VDC for use directly, or in other systems. Variable voltages shall be handled by changing the frequency of the switches located inside the buck converter, which is controlled by the MPPT subsystem via the PWM generator. The result of this allows the buck converter to output 12V no matter the input voltage (no matter the time of day). In the case that the solar panel provides less than 12V, the microcontroller shall switch the system to use battery power. Both the input and output of this subsystem is monitored via the voltage/current sensors, which in turn, feed back into the microcontroller to be displayed through the application.

The DC-AC inverter subsystem will take in 12VDC from the DC-DC converter subsystem and convert it into 12VAC which allows for the use of the electrical grid. It will be made up of switches, a PWM, and other basic elements used in electronic circuits. A step-up transformer will also be used to step-up the 12VAC to 165VAC peak-to-peak, hence producing enough power to efficiently charge the intended electronic device. A voltage and current sensor will monitor the output of the inverter for the purpose of data collection which will be displayed through the user interface application.

Android Application and Website will both use Firebase as a backend database to organize and fetch data that is received from the ESP32. The data displayed consist of the power harnessed from the sun for that specific day, the max power output for a given day, the current, voltage, and power from inside the system, whether or not the system is charging devices using solar power or battery power, the battery level, and the devices that are connected. Where these applications differ is how they’re created. The android app is created using android studio along with angular, while the website will strictly be using angular. By using the same language but in different formats the code for one application will be easily transferable to the other application allowing for easy edit-ability and efficiency in implementation.

Overall, the system gathers energy from the solar panel, then either stores it in a battery or powers the consumer electronics connected to it. Every node will be tracked and delivered to the Phone and Computer application where it can be viewed for either maintenance or leisure purposes.

## Characteristics

### Functional / Performance Requirements

#### Solar Panel Maximum Power Output

The Solar/Battery Power System should function as intended on any and all solar panels that provide up to 260W max power output.

*Rationale: The Solar/battery power system was designed to operate using a 260W max power solar panel. Any solar panel that provides equal to or less than 260W should be able to work with the Solar/battery power system.*

#### Range of Loads

The Solar/Battery Power System shall be able to power all consumer electronics that consume up to 100W either in DC or in AC.

*Rationale: This is a requirement specified by our customer due to constraints of their system in which the Solar/battery power system is integrating.*

### Battery switch

The Solar/Battery Power System shall switch to battery power if the solar panel is not producing enough power.

*Rationale: This is a requirement specified by our customer due to constraints of their system in which the Solar/battery power system is integrating.*

### AC Output

The Solar/Battery Power System shall output AC electricity that is identical to the United States power grid.

*Rationale: This is a requirement specified by our customer due to constraints of their system in which the Solar/battery power system is integrating.*

### Max Power Point Tracing

The Solar/Battery Power System shall be able to trace the maximum power point.

*Rationale: This is a requirement specified by our customer due to constraints of their system in which the Solar/battery power system is integrating.*

### Physical Characteristics

#### Mass

The mass of the Solar/Battery Power System shall be less than or equal to 32 kilograms.

### Electrical Characteristics

#### Inputs

1. The presence or absence of any combination of the input signals in accordance with ICD specifications applied in any sequence shall not damage the Solar/Battery Power System, reduce its life expectancy, or cause any malfunction, either when the unit is powered or when it is not.
2. No sequence of command shall damage the Solar/Battery Power System, reduce its life expectancy, or cause any malfunction.

*Rationale: By design, should limit the chance of damage or malfunction by user/technician error.*

##### Power Consumption

The maximum peak power of the system shall not exceed 260 watts.

*Rationale: This is a requirement specified by our customer due to constraints of their system in which the Solar/Battery Power System is integrating.*

##### Input Voltage Level

The input voltage level for the Solar/Battery Power System generated from the solar panels shall be +0 VDC to +60 VDC.

*Rationale: This is a requirement specified by our customer due to constraints of their system in which the Solar/battery power system is integrating.*

#### Outputs

##### Data Output

The Solar/Battery Power System shall include a website and an android application for users to view information and trends regarding the system.

*Rationale: The Solar/Battery Power information passes directly to the customer’s system.*

##### Diagnostic Output

The Solar/Battery Power System shall include a diagnostic interface for maintenance and data logging.

*Rationale: Provides the ability to control things for debugging manually and a way to view/download the node map with associated potential targets.*

### Environmental Requirements

The Solar/Battery Power System shall be designed to withstand and operate in the environments and laboratory tests specified in the following section.

*Rationale: This is a requirement specified by our customer due to constraints of their system in which the Solar/Battery Power System is integrating.*

#### Thermal

The Solar/Battery Power System shall be able to tolerate outdoor temperatures ranging from -15 °C to 50 °C.

*Rationale: The minimum temperature in Bryan, Texas can reach -5 °C and the maximum temperature can reach 40 °C.*

#### Rain

The Solar/Battery Power System shall be able to function properly in an environment where rain is present.

#### Humidity

The Solar/Battery Power System shall be able to function properly in an environment with humidity levels ranging from 0% to 100%.

*Rationale: This is a requirement specified by our customer due to constraints of their system in which the Search and Rescue System is integrating.*

# Support Requirements

#### Computer or Smartphone with Internet Access

The website will be hosted using firebase, which has to be accessed through the internet. The app can only be downloaded and connected with internet access. To view the data that is displayed on the website and android application, the user must meet this requirement.

*Rationale: Other forms of accessibility to this system are outside the scope of this project.*

#### Local Wifi Access

In order to view the data from the system, the system needs to have access to WiFi so that the ESP32 can communicate with the backend database.

*Rationale: This is the means for the system to communicate with the backend database.*

#### Maintenance

The user should check the website and application daily to ensure proper use and operation of the system.

*Rationale: Environmental factors may inhibit power harnessing, the user should be able to access and clean solar panels if necessary.*

# Appendix A: Acronyms and Abbreviations

MPPT Maximum Power Point Tracking

VDC Volts of Direct Current

VAC Volts of Alternating Current

W Watts

°C Degrees Celsius

UV Ultraviolet

PWM Pulse Width Modulator

# Appendix B: Definition of Terms