PV-Smoothing Software Requirement Specifications

Jonathan Diller, in collaboration with Karen Flieseler and Max Bankert

Penn State Harrisburg
CMPSC 488 - Capstone
Spring 2020

1. Introduction **2**
1.1 Project Overview 2
1.2 Software Overview 2
1.3 Technical Background 2
1.4 Constraints 4
2 High-Level Requirements **5**
2.1 Functional Requirements 5
3. Domain Model **5**
4. Use Cases **7**
5. Use Cases Diagram **8**
6. Project Glossary and Acronyms **9**
7. References **10**

1. Introduction

This document covers the high-level software requirements for the PV-Smoothing Capstone Project. A general overview of the project and its technical background are also included. Any additional software requirements set after this document has been approved will be added to the Appendix of this document.

1.1 Project Overview

In order to increase the efficiency of Photovoltaic (PV) cells, this project seeks to smooth out the fluctuations in solar panel output by usings a DC-to-DC/Buck-Boost converter and battery storage. A microcontroller will be used to analyze panel output and control a gate driver on the Buck-Boost converter in order to smooth the PV system's output [1].

1.2 Software Overview

A TI C2000 Microcontroller will be used to read various sensors, record data, and controller the converter in order to achieve PV smoothing. All of this will be done by software loaded onto the microcontroller. The software will use Proportional Integral (PI) regulator and a Smoothing algorithm to determine what the voltage output of the Buck-Boost converter should be. The microcontroller will control the converter via a Pulse-Width Modulation (PWM) signal.

1.3 Technical Background

PV cells are becoming more popular as a source of energy and are viewed as a more environmentally friendly alternative to fossil fuels. One drawback to solar energy is that panel output tends to fluctuate throughout the day. In addition to the sun's movement across the sky throughout the day, there are several things that affect the performance of PV cells and cause their output to fluctuate. Things such as temperature and partial cloud coverage can greatly affect solar panel output [2]. This can be seen in Figure 1.

A battery storage system and DC-to-DC converter can be used to smooth out the output of PV cells. The battery is used to hold excess energy and filter out the low and high spikes in the output [3]. An example of this smoothing can be seen in Figure 2. In several cases, including this capstone project, a microcontroller is used to evaluate PV cell output and control the DC-to-DC converter. There have been several techniques proposed in literature and implemented in commercially available products that smooth PV output.

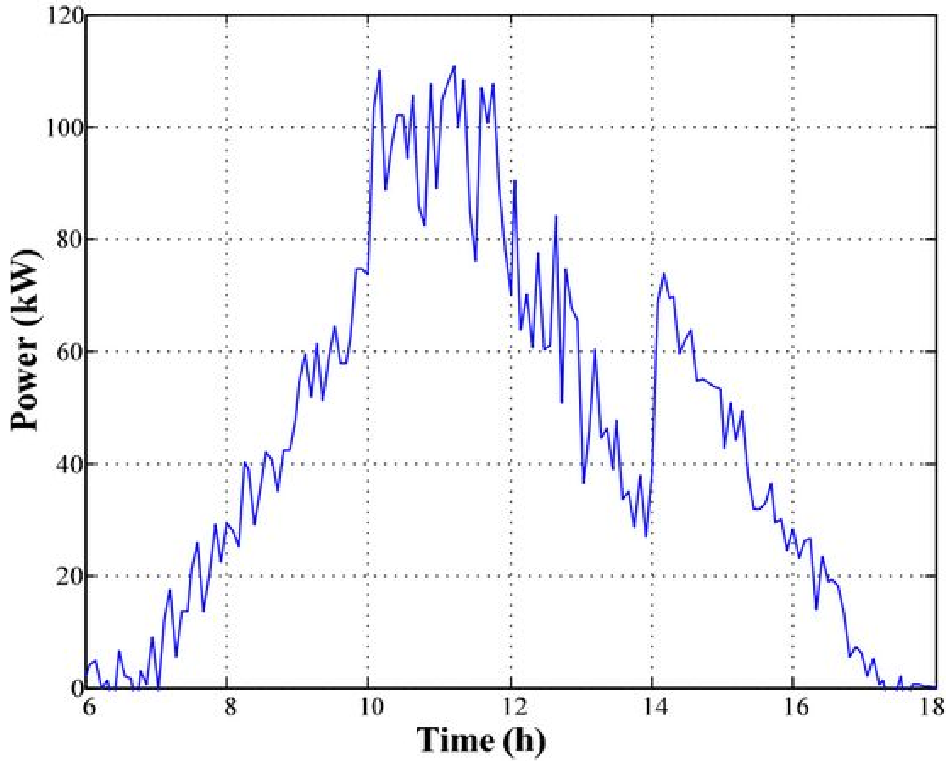


Fig. 1, power output of PV cell throughout the day [2]

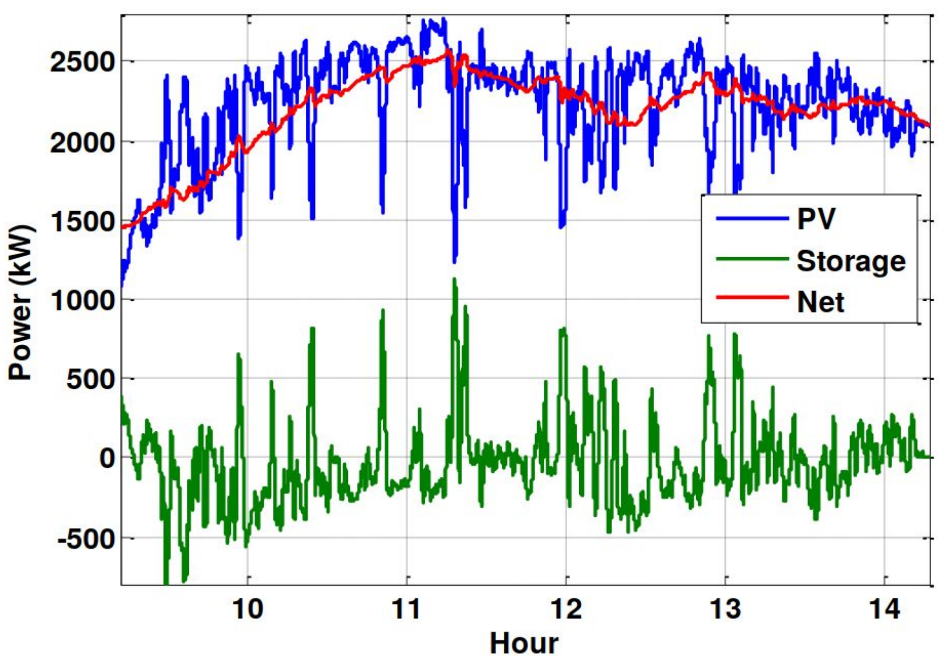


Fig. 2, power output of PV cell, Battery, and Smoothing System (Net) [3]

1.4 Constraints

1. Project must be completed by May 2020.
2. Software production must meet the requirements and timelines specified by the CMPSC 488 course.

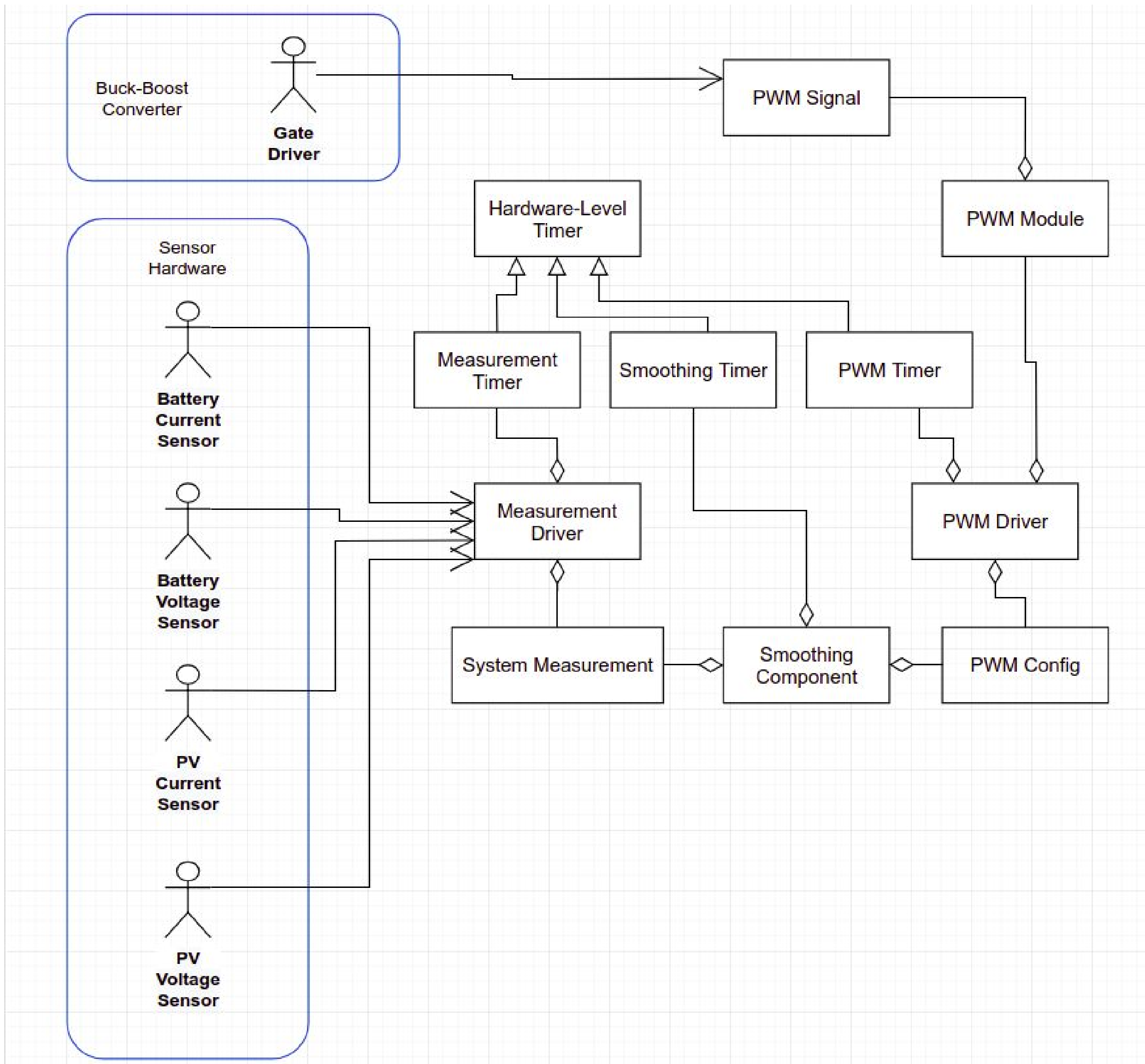
2 High-Level Requirements

This section covers the high-level software requirements. Any additional software requirements made after this document has been approved must be added to the Appendix of this document and will be considered on a case-by-case basis.

2.1 Functional Requirements

1. The microcontroller must read solar panel voltage output values from a voltage sensor.
2. The microcontroller must read battery voltage output values from a voltage sensor.
3. The microcontroller must read solar panel current output values from a current sensor.
4. The microcontroller must read battery current output values from a current sensor
5. The microcontroller software should utilize a smoothing algorithm to achieve optimal PV smoothing performance.
6. The microcontroller must send a PWM signal to the Buck-Boost converter to control the converter’s output.
7. The microcontroller should use a closed-loop PI regulator to control the output power of the battery.

3. Domain Model



4. Use Cases

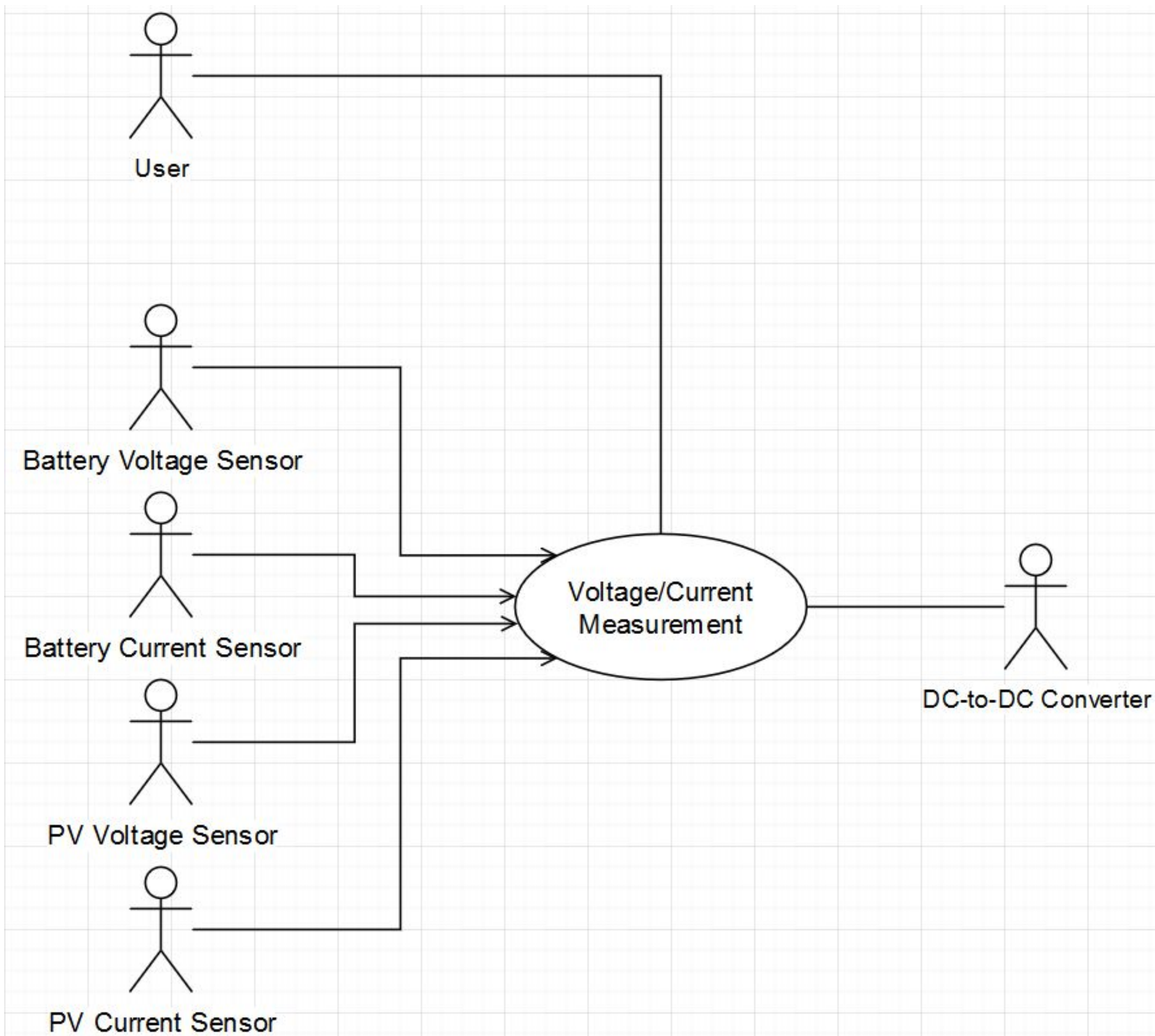
Current/Voltage Measurement

BASIC COURSE:
The User starts up the PV Smoothing System. The system generates a PWM Signal and loops through the following steps indefinitely; reads Voltage, Current, and Battery Sensor input from Senor ADC, checks to see if battery temperature is above limit, performs PI calculation, and updates the PWM Signal.

ALTERNATE COURSES:
Battery temperature is too high: The system shuts off the PWM signal.

NOTE: We do not know how the system will monitor the battery temperature yet. The Electrical Engineering students still need to design this part of the system. Therefore, the details for this part of the system was intentionally left vague.

5. Use Cases Diagram



6. Project Glossary and Acronyms

ADC	Analog to Digital Converter - device that can read an analog electrical signal (usually for 0 V to 3.3 or 5 V) and converts this signal into a digital (integer) value.
CCS	Code Composer Studio - IDE provided by Texas Instruments that is used to develop software for Texas Instruments microcontrollers.
Buck-Boost Converter	A DC-to-DC converter commonly used in power systems.
ISR	Interrupt Service Routine - a function that is run on a microcontroller after an interrupt occurs.
PI Regulator	Proportional Integral Regulator - control-loop technique that utilizes feedback.
PV Cell	Photovoltaic Cell - also known as a solar cell, is a diode that converts sunlight into electrical current.
PWM	Pulse-Width Modulation - an alternating high to low periodical voltage signal that is commonly used in control systems.

7. References

[1] M. Bankert, K. Feiseler, “Capstone Project Proposal: PV Smoothing of a Solar Power System,” *EET 433 Requiremets*, 2019.

[2] H. Liu, J. Peng, Q. Zang, and K. Yang, “Control Strategy of Energy Storage for Smoothing Photovoltaic Power Fluctuations,” *IFAC-PapersOnLine*, vol. 48, no. 28, pp. 162–165, 2015.

[3] M. J. Reno, M. Lave, J. E. Quiroz, and R. J. Broderick, “PV ramp rate smoothing using energy storage to mitigate increased voltage regulator tapping,” *2016 IEEE 43rd Photovoltaic Specialists Conference (PVSC)*, 2016.