All-in-One Photovoltaic Sensor

Senior Design I

Initial Project Document and Group Identification

University of Central Florida

Department of Electrical Engineering and Computer Science

Customer and Sponsor: Orlando Utilities Commission

Group 6

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Project Narrative

As greenhouse gas emissions continue to rise on Earth today, one of the biggest challenges is to find new ways to produce clean energy reliably and efficiently. Many companies around the world have set a goal of reaching carbon neutrality to combat global warming. The Orlando Utilities Commission (OUC) is one of many companies which has established a similar goal; OUC's goal is to reach 50% carbon neutrality by 2030, and to reach 100% carbon neutrality by 2050. Our group has taken a part in OUC's objective to achieve sustainable energy production by developing data sensing equipment to pair with OUC's existing solar panel array.

The goal of our project is to develop a low-cost, all-in-one photovoltaic (PV) sensor device which will allow our customer, OUC, to gather data from their solar panel arrays. The all-in-one sensor will be able to collect voltage, current, temperature, and irradiance directly from the customer's solar panels. The data that our solution will provide the customer with includes numerous benefits. Firstly, through voltage and current values collected at each panel in an array will allow for technicians to detect a faulty panel in an easy-to-use manner. This solution would significantly reduce loss of power generation when a panel becomes faulty as this would reduce the time [and money] it would take for a technician to identify a faulty panel. Secondly, our solution will collect large amounts of granular data for OUC to generate accurate representations of temperature and irradiance at a solar panel array over a period, as well as energy collected over a period.

Our all-in-one PV sensor will function as a series of collector nodes, or microcontrollers, mounted onto each solar panel in an array. The collector nodes will be able to collect and wirelessly transmit multiple, granular pieces of data like voltage and current, temperature, and irradiance from the onboard DC optimizers, thermocouples, and pyrometers, respectively, to a receiver node. The receiver node will be able to compile collected data into a database, as well as display collected data in real-time. It is from our solution that OUC will be able to reach 50% carbon neutrality by 2030 and achieve 100% carbon neutrality by 2050 as our all-in-one PV sensor will have a robust design that will allow for scalability to

Market Analysis and Customer Needs

Getting the measurement of the Voltage, current, temperature, and radiance on an array of solar panels are important bits of information that can help deduce problems with panels; and even understand and find ways to improve performance of panels. OUC, knowing this, tried to implement methods to acquire these measurements, but unfortunately were unsuccessful at developing effective solutions to combat the issue. So, we would now look at some of the solutions they tried to develop to give us a better idea of how to approach the project.

OUC installed a Solar Edge DC Optimizers that modulated the output voltage of the solar panel, maintaining string voltage. The Optimizers continuously receive data from the panel regarding the DC data that outputs from the panel over time; wirelessly transmitting information to an inverter close by. Although this might have seemed like a solution, the data recorded by the optimizer could not actually be viewed by the company. OUC tried many methods to receive this data, even using python to access the information; or requesting the data from Solar Edge directly, but none of their attempts proved any result. Even still, the optimizer would not help to find issues pertaining to certain panels that have malfunctioned, but would modulate DC voltage, producing less power than expect. As a result, OUC would not know which panel is not working; only having a general view on which array has a problem. So, we can see why the DC Optimizer could not provide a definite solution.

Understanding the problem this rose, Rubin York even began to implement a device that would send a warning if a panel started to malfunction, and not output the required power. He devised a system to record the amperage flow, by using a voltage divider, a buck converter, and a Broadcom ACHS-7122-000E sensor. This proved successful to a point, being able to capture the current flowing through the circuit; however, there appeared to be some amount of electrical noise in the reading. Also, Rubin still had to go to each panel to measure the performance of each panel. Knowing that his idea was possible, he assembled a senior design team to design a device that could get the readings stated above. The team used a raspberry pie, banana pie, and an orange pie as sensors. They also used different ICs to receive the desired information. Although they had a good attempt, the final product could only successfully record the Voltage and radiance.

We are now tasked with the same project. We are to design a device that can read and display the data of the Voltage, current, temperature, and irradiance of an array of solar panels, measuring specific points on the panel. Our device would be able to identify problematic panels due to the readings and would be able to inform the company of the data collected. Thanks to the efforts of Rubin and our predecessors, we were able to get a clearer vision on how to approach the problem. So, now we would use the technology at hand, and any other electrical components to achieve the desired result we are required to produce.

Requirement Specifications

Table 1: Specifications

	Requirement	Specification
1	Power supply	Solar panel
2	Available input power	1500 watts
3	Sample rate	10-15 seconds
4	Specific cost	<$20
5	Connection to Solar panels	MC4
6	Accurate Voltage Measuring	Moderate Priority
7	Accurate Radiance Measuring	Moderate Priority
8	Accurate Temperature Measuring	Within 5% of real value
9	Accurate Current Measuring	Within 5% of real value
10	Wireless Data Transfer	Effective data transfer
11	Protective packaging	Harsh weather resistant

Constraints and Related Standards

Table 2: Constraints and Specifications

	Requirement Specifications	Priority
1	Input voltage power supply 39V DC	High
2	Input power range 500 to 1200 W level	High
3	MC4 Standard connections	High
4	Removable device	High
5	Cost per sensor less than $20	Moderate
6	Accommodation terminal connectors 10 AWG wire	Low
7	Connection between DC Optimizers	High
8	Designing with thermocouple and pyranometer ports	Moderate
9	Sensor Durability lifetime more than a year	Low
10	Testing point time at least a week	Moderate
11	All other requirements standard	High

Constraints

In this project we are facing two major types of constraints. Constraints imposed by the customer/sponsor and real constraints which are standard requirements when designing.

Customer Constraints

Those constraints are

- Position of the device
- Device cost need to challenge market price related to market constraint and economic constraints
- Strick to customer/sponsor terminal connectors (MC4 connector, thermocouple and pyranometer ports)

Real constraints

Are all standard requirements for the design

- DC/DC Power supply
- Safety design
- Testing Process
- Reliability
- All standard connections
- Programming languages

Block Diagrams

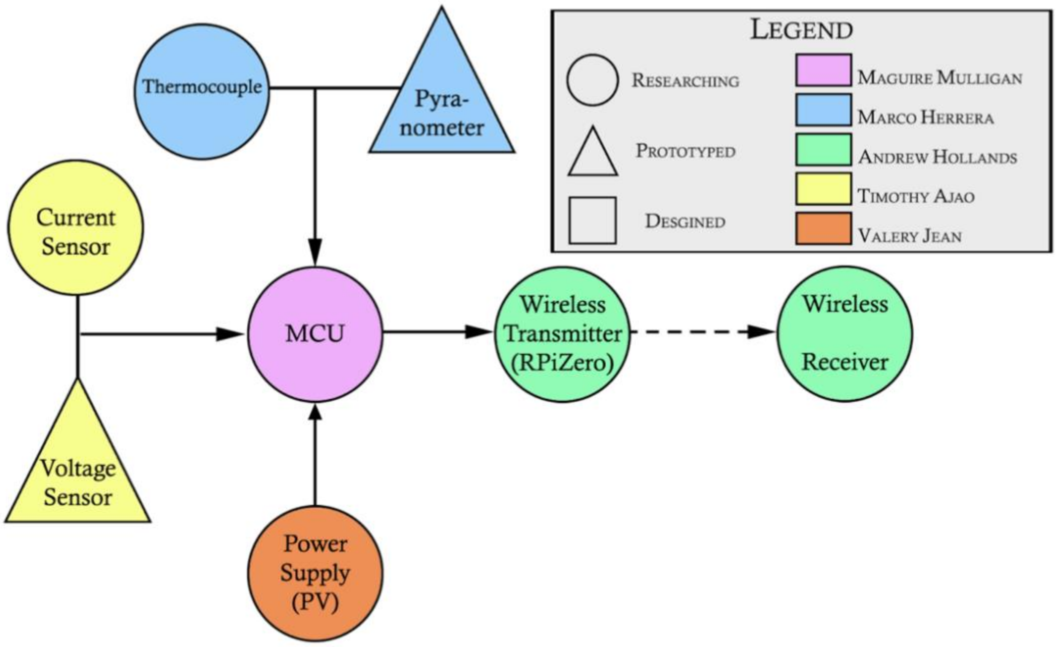

Figure 1: Hardware Block Diagram

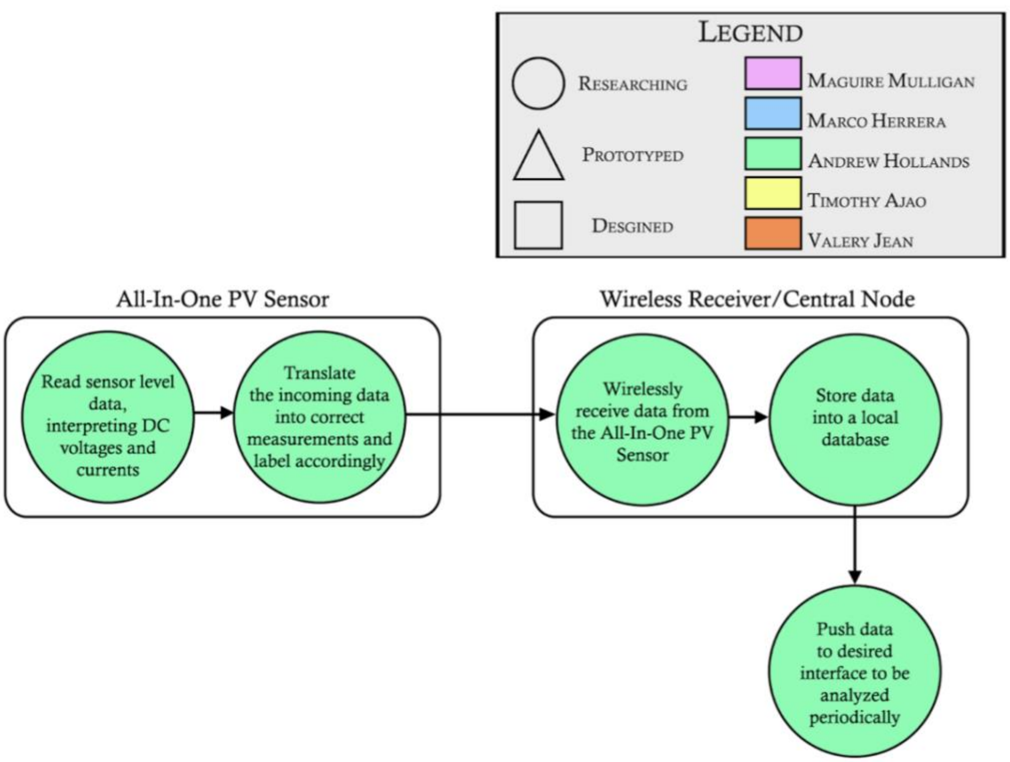

Figure 2: Software Block Diagram

Prototype Illustration

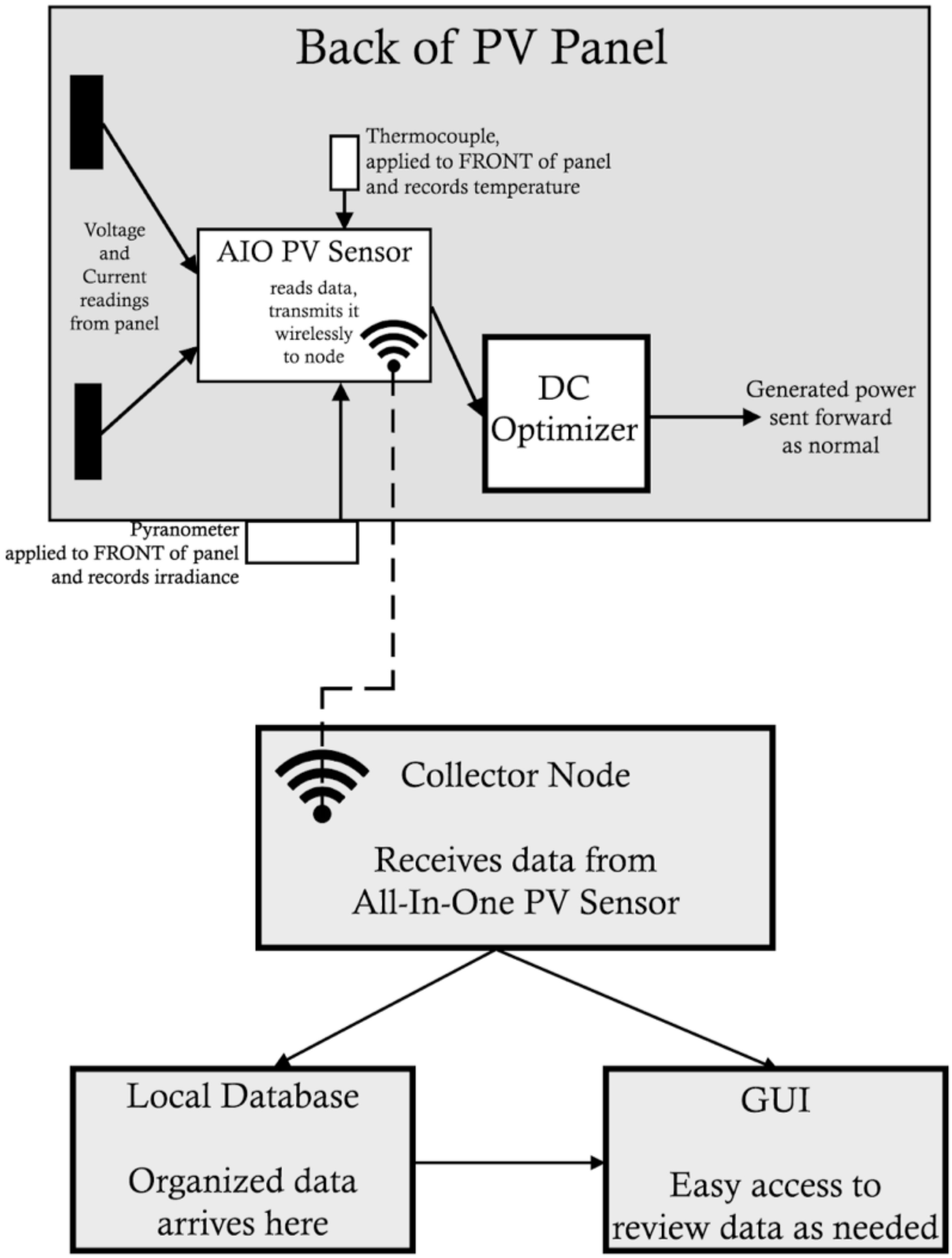

Figure 3: Prototype Design

Budget

Table 3: Initial Project Budget for Re-designing Phase I

	Part Number	Component Description	Vendor	Unit Price	Quantity	Total Price
1		Raspberry Pi 4 Model B 2019 Quad Core 64 Bit WiFi Bluetooth (4GB)	Amazon	$134.99	2	$269.98
2	ISO 9060:2018	SP-110-SS: Self-Powered Pyranometer	Apogee Instruments/ Part provided by OUC	$223.00	3	$446
3	TTSS-14E-4	Thermocouple Probes with Lead Wire & Molded Transition	Omega/ Part Provided by OUC	$30.42	3	$91.26
4		Raspberry Pi Zero 2 W (Wireless / Bluetooth)	Amazon	$49.99	4	$199.96
5	PCB with Components			$10	3	$30
Total Estimated Cost:						$1,037.20

Table 4: Initial Project Budget New Design

	Part Number	Component Description	Vendor	Unit Price	Quantity	Total Price
1	3-01-1287	ESP-32S Development Board 2.4GHz Dual-Mode Wi-Fi	Amazon	$10.99	6	$65.94
2	ISO 9060:2018	SP-110-SS: Self-Powered Pyranometer	Apogee Instruments/ Part provided by OUC	$223.00	3	$446
3	TTSS-14E-4	Thermocouple Probes with Lead Wire & Molded Transition	Omega/ Part Provided by OUC	$30.42	3	$91.26
5	PCB with Components	To be determined	To be determined	$10	3	$30
Total Estimated Cost:						$633.20

Project Milestones

Table 5: Senior Design I Milestones

Number	Milestone	Tasked	Start Date	End Date	Status
Introduction to Project					
1	Meet the team, advisors, and customer	Group 6	1/11/2022	1/17/2022	Completed
2	Familiarize with the project	Group 6	1/17/2022	1/25/2022	Completed
3	Scout the location for implementation	Group 6	1/25/2022	1/27/2022	Completed
4	Role Assignments with tech advisor	Group 6	1/25/2022	1/28/2022	Completed
5	Part Identification and Classification	Group 6	1/27/2022	2/4/2022	In-Progress
Project Documentation					
6	Initial Project Document	Group 6	1/24/2022	2/4/2022	Completed
7	Updated Divide and Conquer Doc.	Group 6	2/12/2022	2/18/2022	In-Progress
8	First Draft Senior Design I	Group 6	2/14/2022	3/25/2022	Pending
9	Second Draft Senior Design I Rev.	Group 6	3/28/2022	4/8/2022	Pending
10	Final Report	Group 6	4/11/2022	4/26/2022	Pending
Research and Development					
11	Thermocouple and Hall-Effect Sensors	Marco	1/28/2022	2/18/2022	In-Progress
12	Node/MCU and Communication	Andrew	1/28/2022	2/18/2022	In-Progress
13	Node/MCU and Pyranometer	Maguire	1/28/2022	2/18/2022	In-Progress
14	Power and Hall-Effect Sensor	Timothy	1/28/2022	2/18/2022	In-Progress
15	Power and Voltage Sensor	Valery	1/28/2022	2/18/2022	In-Progress
16	Filtering Circuit and Amplification	Group 6	2/4/2022	2/18/2022	In-Progress
17	Board Prototyping V1&V2	Group 6	2/21/2022	3/28/2022	Pending
18	Final Prototypes Stress Tests	Group 6	3/14/2022	5/3/2022	Pending
19	PCB Layout	Group 6	3/28/2022	5/3/2022	Pending

Table 6: Senior Design II Milestones

Number	Milestone	Tasked	Start Date	End Date	Status
1	Working PCB V1 Stress Test	Group 6	4/27/2022	5/30/2022	Pending
2	Final PCB Stress Test	Group 6	5/16/2022	7/4/2022	Pending
3	All in Once PV Sensor	Group 6	5/16/2022	7/18/2022	Pending
4	Conference Paper	Group 6	5/16/2022	7/26/2022	Pending
5	Design Demonstration	Group 6	5/26/2022	7/26/2022	Pending

Resources

I. “Raspberry Pi 1 Model B+,” Raspberry Pi. https://www.raspberrypi.org/products/raspberry-pi-1-model-b-plus/ .

II. “SP-110-SS: Self-Powered Pyranometer,” Apogee Instruments, Inc. https://www.apogeeinstruments.com/sp-110-ss-self-powered-pyranometer/#product-tab-information

III. “Raspberry Pi Zero W,” Raspberry Pi. https://www.raspberrypi.org/products/raspberry-pi-zero-w/

IV. “Thermocouple types,” https://www.omega.com/en-us/resources/thermocouple-types

V. “Omega Sensors,” https://www.omega.com/en-us/

VI. “ESP32 Technical Reference Manual,” https://www.espressif.com/sites/default/files/documentation/esp32_technical_reference_manual_en.pdf