Design Review 3:

Microgrid Team

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1 Introduction

In this design review, we will show our working integrated system. This involves showing our main interfaces and our essential functions, discussed in detail in the following section. After that, we will look at our final board design, which has been ordered and recently delivered. Finally, we will review our bill of materials.

2 System's End to End Functioning

Main Interfaces

Generation & Distribution

The solar cells were wired together with the Distribution Subsystem. The team was able to confirm that the generation points fulfill the essential function of providing power to the distribution lines and are capable of providing power to the loads. Both generation points are hooked up to the distribution subsystems at this point.

Distribution & Control (Switching) System

The SSRs were wired together with the Distribution Subsystem. The team was able to confirm that the SSRs of the Control System Subsystem fulfill the essential function of switching between battery discharging (battery providing power to the loads) and battery charging (generation/solar cells providing power to attempt to charge the battery). Using the voltage-based power monitoring data from each of the load and generation point and battery storage, the microcontroller calculates voltage, current, and power of each respective subsystem. This data is then used to determine the switching behavior via SSRs inputs (digital output pins on control microcontroller board), which correspondingly alters the circuit pathways of the Distribution Subsystem.

Control (Switching) System & Battery Storage System

The SSR switching system monitors the power at the loads and switches the battery input/output lines based on demand. If there is no load demand, then the output line is opened and the input line is closed so that the battery can store unused power from the solar panels. If there is load demand, the input line is opened and the output line is closed so that the battery can support the loads.

The storage system has been successfully integrated with the SSR switching system. The output line is a simple connection to the battery. The receive line passes the voltage through a boost converter, from 12V to 14V, and then through a charge controller before it is connected to the battery. To monitor the voltage and current of the battery, the team implemented a shunt resistor and a system of voltage dividers to step down the voltage readings to a level that can be read by the boards.

Distribution & Loads

The DC distribution system was connected and verified that power was being transferred between the variable load, both generation inputs, and the battery input/output. The power monitoring voltage divider was successfully implemented across both branches of the variable load, allowing voltage data to be read into the first power monitoring board.
Next steps include wiring up a voltage divider across the motor load once the second power monitoring board is configured, allowing data to be transmitted in the same way to the control board.

Power Monitoring & Load/Generation/Battery Storage System

Voltage dividers were designed and set up at each generation point, at the battery, and at the variable load. Using analog -in pins on the microcontroller, values were successfully read in at the variable load, using analog input scanning to read in convert two analog inputs simultaneously. These values were then sent via UART to the control board where they are sent to the display subsystem.
Once finalized, each power monitoring board will simultaneously read in 4 analog inputs (two for load and two for generation), and send the data via UART to the control board. Each load and generation will be assigned a unique ascii start character that the control board will use to determine which load or generation it is receiving data from. As for power monitoring of the Battery Storage Subsystem, the analog input values will not need to be sent via UART to the control board because monitoring the battery voltage, current, and power data is contained within the same microcontroller that sends this data to the Display Subsystem and performs switching operations via SSR input signals(digital output high or low on PIC32MM).
Once the control microcontroller board receives all voltage-based power monitoring data from each of the load and generation points, as well as reads those values for the Battery Storage Subsystem, the microcontroller performs calculations for voltage, current, and power of each respective subsystem. This data is then used to determine the switching behavior via SSRs.

Power monitoring to Display Subsystem

Currently, the display system is being connected directly to the power monitoring subsystem to read in the information at the load. The tx and rx pins on the board were connected serially to a PC via a UART to USB COM port converter. The display system successfully received the power analog data but in type ascii and so conversion to decimal is necessary. After converting the transmitted values, the system will use known values to calculate the current and power in the same way as the control system.
Identical to the battery storage system, at the load and each generation the team implemented a shunt resistor and a system of voltage dividers to step down the voltage readings to a level that can be read by the boards. The voltage dropped over the smaller resistance values is measured. The voltage on either side of the shunt resistor is then calculated, using the knowledge that the voltage at these nodes equals the measured voltage times the summation of all resistance values divided by the resistance that is being measured over. These two resulting voltages are then subtracted to find the voltage drop over the shunt resistor. This value is then

divided by the known resistance of our shunt resistor to find the current through the load, generation, or battery. We also know the voltage across the load, generation, or battery, since this is just the voltage on the lower-voltage node of the shunt resistor. Finally, the power is calculated by multiplying the voltage across the load, generation, or battery by the current through the load, generation, or battery.

3 Final Board Design

Below are the schematic and board for our final board design. We ordered three copies of the board, each with the capability of monitoring power, controlling switching, and communicating.

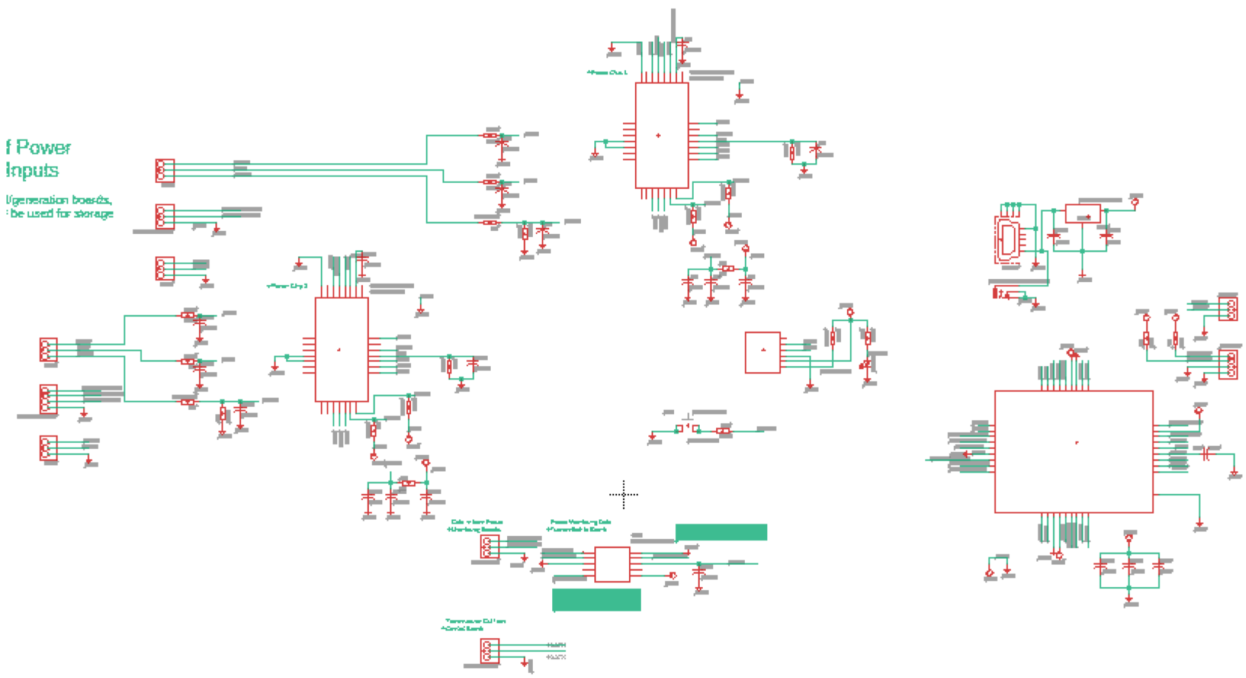

Figure 1. Overview of Schematic of Finished Board

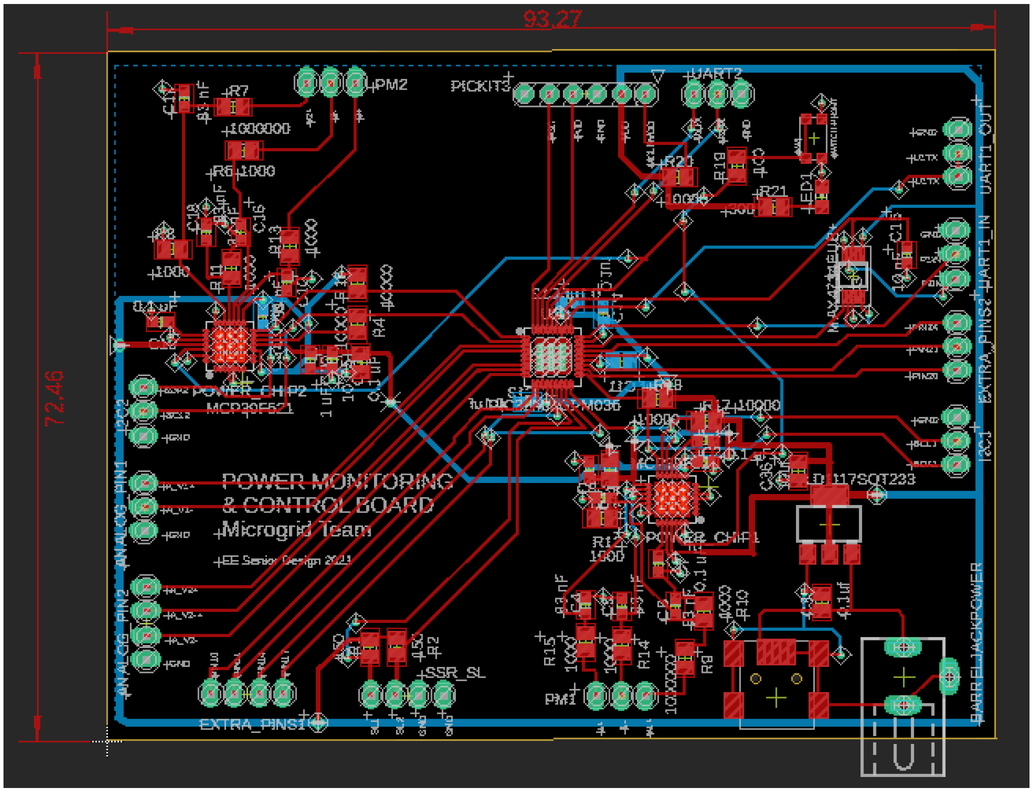

Figure 2. Eagle Board Completely Routed

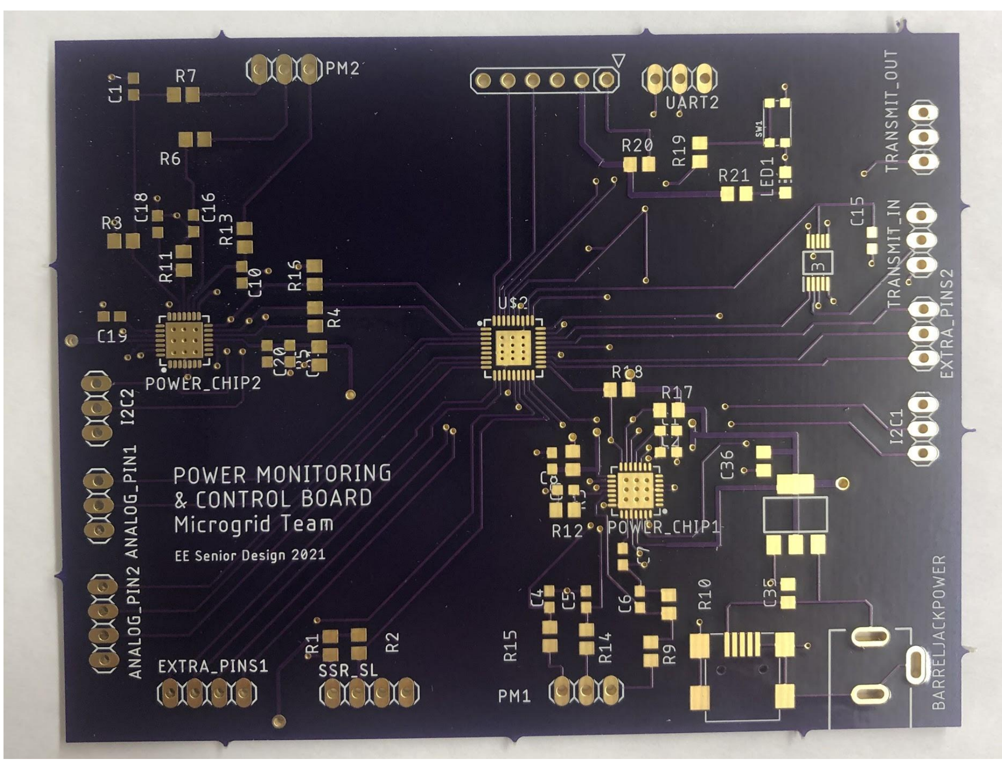

Figure 3. Finished Product

4 Bill of Materials

Throughout our project, our group has kept a careful eye on our budget. We were successful in staying under our $500 budget, only spending $413.47. The following figure outlines how we have spent this money.

System	Part	Website ordering from	Cost per unit	Number of units Needed for Total Project	Shipping and Tax	Total Cost	Notes
Battery	1A Fuse	Mouser	$0.21	3		$0.63	
Battery	Charge Controller	Amazon	$13.99	1	$0.98	$14.97	
Battery	Boost Converter	Amazon	$8.39	1	$0.59	$8.98	
Battery	Batteries	N/A	$0.00	2		$0.00	Plan to use Professor Schafer's
Control	SSR	Amazon	$8.95	3	$1.89	$28.74	
Control	10W 10ohm resistors for SSR output	Amazon	$6.99	1	$0.49	$7.48	Pack of 10
Control	Buck Converter	Amazon	$10.99	1	$0.77	$11.76	
Control/Power Monitoring	PIC32MM0256GPM036	Microchip Technology	$0.00	3		$0.00	Ordered free samples
Distribution	630mA Fuse	Mouser	$0.24	5		$1.20	
Distribution	12AWG Wire	Amazon	$9.99	1		$9.99	
Distribution	12VDC-110VAC Inverter	Amazon	$17.95	1		$17.95	Not being used, but unreturnable
Distribution	110VAC-12VAC Transformer	Amazon	$15.99	1		$15.99	Not being used, but unreturnable
Distribution	120VAC-12VDC Rectifier	Amazon	$15.48	1		$15.48	Not being used, but unreturnable
Distribution	Buck Converter	Amazon	$10.99	1		$10.99	Not being used, but unreturnable
General	Wire T-Taps	Amazon	$10.99	1	$7.19	$18.18	
General	2-Prong Outlets	Amazon	$2.98	1		$2.98	Not being used, but unreturnable
General	2-Prong Plugs	Amazon	$6.80	1		$6.80	Not being used, but unreturnable
General	Fuse Holders	Amazon	$4.49	1		$4.49	Pack of 5
General	PCB	Oshpark	$55.00	1		$55.00	
General	0.1ohm 2W resistors	Amazon	$6.08	1	$0.43	$6.51	Pack of 15
Generation	Solar Cells	Amazon	$14.99	4	$4.20	$64.16	Pack of 4
Generation	630mA Fuses	Mouser	$0.24	4		$0.96	
Generation	Sun-simulating Lamp	N/A	$0.00	1		$0.00	Plan to use Kelsey's lamp
LoRa	Module	Digikey	$13.44	3		$40.32	Not being used, but unreturnable
LoRa	915MHz Antenna	Digikey	$4.64	3		$13.92	Not being used, but unreturnable
LoRa	PCB antenna edge mount (5pc)	Amazon	$6.99	1		$6.99	Not being used, but unreturnable
LoRa	Protyping LoRa adapter board	Tindie	$3.00	2	$3.15	$9.15	Not being used, but unreturnable
Power Monitoring	Multiplexers (MCT4734EUB+)	Mouser	$2.71	6	$7.99	$24.25	
Power Monitoring (prototyping)	PCB adapter board	Digikey	$6.00	1	$9.60	$15.60	

Figure 4. List of Project Expenses Incurred

5 Conclusions

The system's end-to-end functionality operates as planned. The design changes include implementing a DC distribution system instead of an AC one, using analog pins over a designated power chip for power monitoring, and using wired UART communication instead of wireless LoRa. These changes allowed the team to implement a system that successfully accomplishes the core goals of the project. Before the final demonstration, the team intends to include power monitoring at the motor load, both generations, and the battery system, as well as implement the PCBs designed specifically for this project instead of the boards from last semester.