EEL 4914: Senior Design 1 Fall 2020

Initial Divide and Conquer Document - Version 2.0

UNIVERSITY OF CENTRAL FLORIDA, UCF
DEPARTMENT OF ELECTRICAL ENGINEERING & COMPUTER SCIENCE

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Interactive Power Distribution Simulation Center that demonstrates the enhanced situational awareness capabilities using phasor measurements

1. Project Description

1.1 Background

With increased renewable integration, the grid-of-the-future is becoming increasingly complex to manage. Because of this, better ways to monitor and manage the complexity of the grid is required. On January 11th, 2019, a unit in TECO Energy Inc., or Tampa Electric Company, was vibrating and it led to frequency oscillations in the entire eastern interconnect, as shown in figure 1. These oscillations lasted for approximately 15 minutes. The event was solved after an operator at TECO noticed the unit's vibrations and decided to shut it off. Florida Power and Light (FPL) knew that there were frequency oscillations, but they did not have enough information to detect the source of the event or its location.

Independent System Operator New England (ISO-NE) knew within seconds that the location of the source of the frequency oscillations was outside their regions and that it was coming from the South. This is because they had WAMS, or Wide Area Management System. With the use of Phasor Measurement Units (PMUs), WAMS increases situational awareness and allows for faster diagnosis of system events. If FPL had WAMS during this event, they would have detected the location of the source of the event within seconds. FPL is currently implementing WAMS into their energy management system at transmission level.

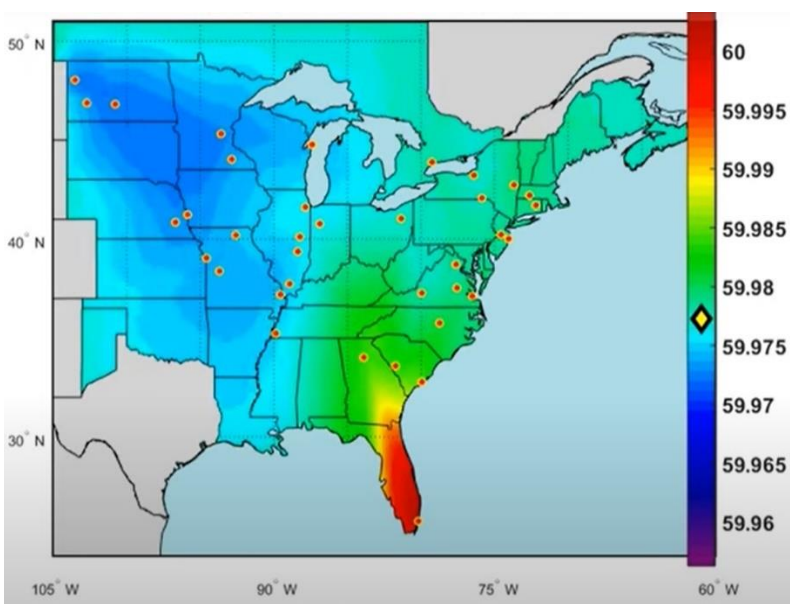


Figure 1: Frequency Oscillations on January 11th, 2019

1.2 Goal and Objective

With increased penetration of edge-of-the-grid devices, such as solar panels, the distribution system is becoming highly complex to manage. After implementing WAMS into FPL's transmission system, they will investigate the possibility of implementing it to their distribution system. For this reason, this project will focus on implementing WAMS in the distribution grid operations.

An easy to use interactive touch table will be developed to demonstrate and educate students and visitors on power systems. It will emphasize the importance of increasing situational awareness and allow for users to have an interactive way of learning about small-scale solar panels. This will be done through a real-time simulation of a distribution power system model that will generate PMU data.

A software module will receive this PMU data and identify the source of the event and its location. This will all be displayed in the table, and the user will be able to choose from types of disturbances and see how it affects the grid. In addition, users will be able to control the angle of a solar panel to see how much the angle change affects its power output. All these features will allow students and/or visitors to learn about power systems in a more interactive way.

Table 1 shows an overview of our goals for this project and classifies them into basic, advanced, and stretch goals. We anticipate finishing the basic goals and some of the advanced goals during Senior Design. We may be able to get to stretch goals, but those may need to be completed after graduation.

Table 1: Goals Overview

Goal Type	Description
Basic	Interactive touch table that displays the distribution system and users can select from types of disturbances and see how it affects the grid. Users can change the angle of a solar panel from the interactive touch table and see how the angle affects its power output.
Advanced	In addition to the basic goal, WAMS algorithm analyzes the data and determines the type of disturbance and its location.
Stretch	Furthermore, the phasor values from the solar panel are fed to the distribution system model to create disturbances. Users will be able to log-in to the table. The table will have a voice recognition feature and it will have a sensor to automatically turn the table on when there is someone nearby and turn it off when no one is near.

2. Requirements and Specifications

Table 2 shows the engineering and marketing requirements that our system must satisfy in order to be successful and satisfy FPL's needs. In addition, the table specifies which requirements will be demonstrated to the review panel.

Table 2: Requirements and Specifications

Marketing Requirements	Engineering Requirements	Justification	Review Panel Demo
6	1. The system should process the following parameters: voltage and current phasor quantities, frequency, and rate of change of frequency (ROCOF). The system should also communicate these parameters.	Modern power systems that are based on Phasor Measurement Units (PMUs) follow the IEEEC37.118.2005 standard. The system being modelled must follow this standard	✓
3, 4, 12	2. The touchscreen should be multitouch enabled. Total number of multitouch points should be at least 2. It should also support common gesture functions found on smart phones or tablets.	Multitouch touchscreen of at least two points and above is very popular and has an increasing market share because they offer excellent user experience	
7, 12	3. Solar panel capable of generating maximum power output of 100 W and at least 12 V output	Compact design/lightweight for easier motor movement, mounting, and solar tracking	
12	4. 3-phase 60 Hz power system model with at least 2 buses.	Power Systems in the United States supply 3-phase electricity and operates at 60 Hz.	
8	5. Wireless communication capable of operating in the 2.4 GHz and 5 GHz band.	802.11a/b//g/ac Wireless Communication Standard enables communication in these bands.	
1, 2	6. Stand-alone MCU with advanced processing capabilities to connect to the touch table.	The MCU must support the needed Linux based Operating System (OS) capable of connecting with OPAL-RT and processing real-time and simulation data. The OS must be able to support the user interface and accompanying graphics.	✓

7	7. Device capable of producing torque to move a solar panel weighing about 20 kg.	Solar panel generating 100 W at 12 V weigh around 16-20 kg.	✓
11	8. The UI should include status indicator light to indicate that the system is on, receiving/transmitting data, and that an event is detected.	It's popular for electronic devices to offer visual machine interface to communicate device status quickly to users.	
10, 12	9. The system should be able to detect that there is an event and locate the source of that event in at most 5 s.	Power control systems need to be able to identify system events in near real-time. Run time for processing big data is usually exponential, and this system should be able to process data sets quickly even as the amount of data increases.	

Marketing Requirements

1. The system should process real-time data
2. The system should be able to process big data
3. The display should have multi-touch capabilities
4. The display should respond to user's command quickly
5. The User Interface should be easy to use
6. The system should meet IEEE.C37.118 standard
7. The system should include Solar panel and supported components
8. The system should be able to communicate wirelessly using 802.11a/b/c/n/ac standard
9. The system should be low cost
10. The system should detect and locate power system events
11. The indicator light should turn on shortly after event is detected/located
12. The system should educate users about power system topics in an interactive learning style

3. Block Diagrams

Figure 2 is the block diagram showing the system architecture for the project. The gray block represents the PCB and corresponding modules. The blue block represents an architecture for collecting and receiving real-time data, and the green block represents a Raspberry Pi which will be used to process the data and build the interactive user interface which will be implemented on the touch table which is represented by the yellow block. Figure 3 is a software flow diagram which depicts how the information will be passed and processed.

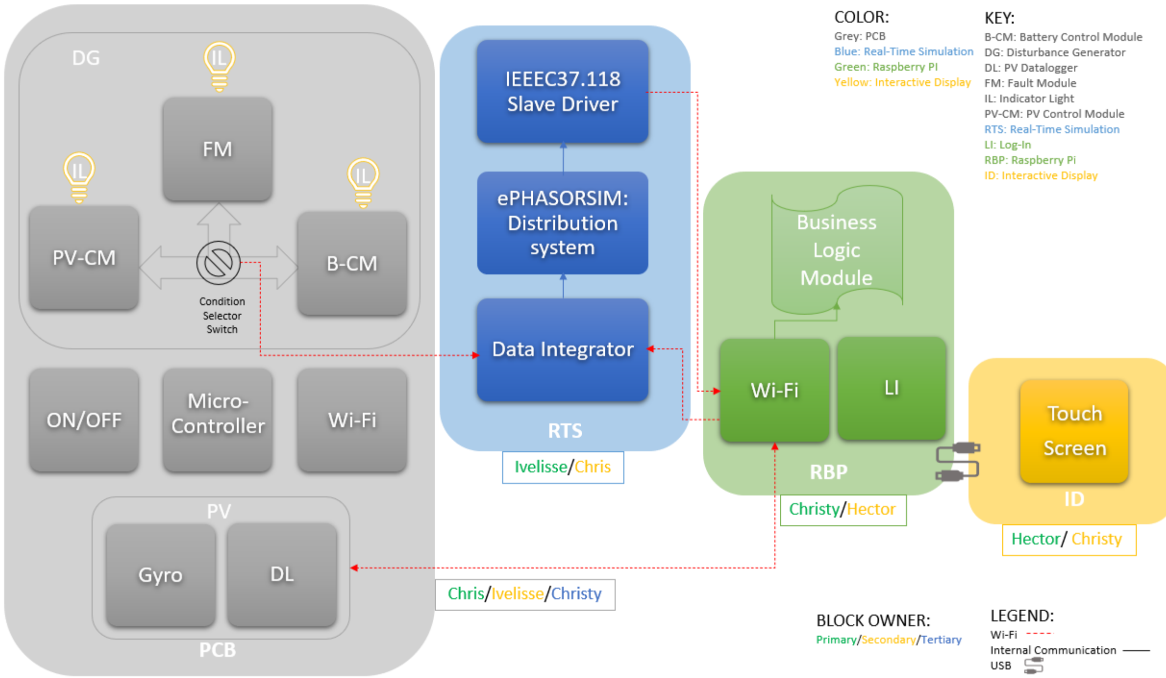


Figure 2: System Architecture

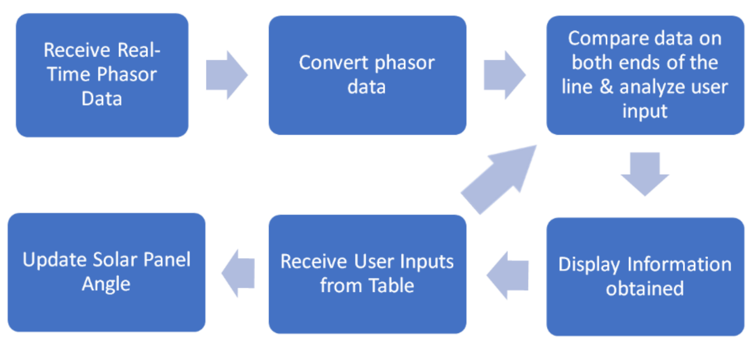


Figure 3: Software Diagram

4. Budget and Financing

Table 3 displays the itemized budget for this project which will be fully sponsored by FPL. We have been able to accurately price most of the parts, but we will not know the exact price on the PCB until it is designed.

Table 3: Itemized Budget

Item	Price	Qty.	Total	Description
Solar Panel	$110.43	1	$110.43	12 V
Motor	$17.88	1	$17.88	High Torque 20 KG Digital Servo Motor
Touch Screen	$1,678.00	1	$1678.00	55" multi-touch full HD screen: 4.17 ft width and 2.43 ft height – Power Consumption: 76 W
Raspberry Pi	$39.71	1	$39.71	Raspberry SC15184 Pi 4 Model B Quad Core 64 Bit 2GB
PCB	~$60 - $100	1	~$60 – $100	
Table Parts	~$150	1	~$150	wood, screws, brackets, casters
Wi-fi USB adapter	$17.49	1	$17.49	EDIMAX
Final Estimate			~$2114.00	

5. Project Milestones

Table 4 details the project milestones, anticipated timeframes and dates, and which team members will be working on each milestone. This table includes information for both semesters of Senior Design thereby covering the entire project's timeline.

Table 4: Project Milestones

Project Milestones Senior Design I - FALL 2020 (08/24/2020 - 12/12/2020)				
1	Choose Final 2 Projects	3 weeks	08/24 - 09/11	All
2	D&C v1.0 2.1: Smart Home 2.2: Interactive touch table	1 week	09/11 - 09/18	2.1: Chris & Christy 2.2: Hector & Ivelisse
3	D&C meeting with advisors	30 min.	09/23	All
4	Research on how to change PV angle	2 weeks	09/18 - 10/02	Chris
5	Research user interference 1. How will users log in 2. How can graphs/maps be displayed	2 weeks	09/18 - 10/02	Hector
6	Start WAMS Algorithm	2 weeks	09/18 - 10/02	Christy
7	Research how to connect wi-fi into OPAL-RT to receive data 1. Use example model	2 weeks	09/18 - 10/02	Ivelisse
8	D&C v2.0	2 weeks	09/18 - 10/02	All
9	Start building ePHASORSIM model	1 week	10/02 - 10/08	Ivelisse

10	Research on how to send power output and angle from Solar Panel through PCB	1 week	10/02 - 10/08	Chris
11	Research how to decode the C37.118 inputs at RBP	1 week	10/02 - 10/08	Hector
12	Research how to generate and choose the type of disturbance from PCB	1 week	10/02 - 10/08	Christy
13	Final Decision on what goes on the PCB 1. Start PCB Design	2 weeks	10/08 - 10/22	All
14	Order PCB and buy all other parts	1 week	10/22 – 10/29	All
15	60 page Draft	2 weeks	10/29 - 11/13	All
16	Final Documentation		12/8	All
Senior Design II - SPRING 2021 (01/11/2021 - 05/04/2021)				
1	Build Prototype	7 weeks	01/11 – 03/1	All
2	Test, Redesign, Test	7 weeks	02/1 - 03/22	All
3	Plan demonstration		?	All
4	Start talking to potential panel		?	All
5	Final Prototype		?	All
6	Peer Presentation		?	All
7	Final Report		?	All
8	Final Presentation		?	All

6. Decision Matrix

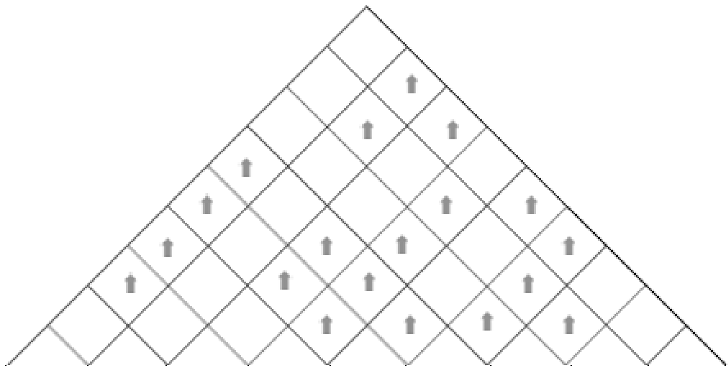
Table 5 is a decision matrix for various features of the project. The matrix provides the pros and cons for these options to assist in deciding how we will implement the features mentioned in the table.

Table 5: Options Matrix for Project Idea

Option	Pros	Cons
Build our own distribution model	1. Experience gained	1. Extra work 2. Not tested
Use an existing distribution model	1. Tested and approved model by IEEE	
Buy a battery	1. Store energy produced from Solar Panels	1. Additional Cost
Buy a touch screen monitor	1. Small amount of testing needed 2. Easy setup 3. Cheaper option	1. Specific sizes make variant price points
Build our own touch screen monitor	1. Built to our specifications and needs	1. Extra work

7. House of Quality

The house of quality (HOQ) developed from Table 2, is shown in figure 4. The marketing requirements are represented in the row headings and the engineering requirements in the column headings.



		Real-time analysis of phasor data	Smart and interactive UI	Fast and simple Event detection	Data transfer between components	MCU data processing algorithm	Power system Model	PV data module	Motor Module	Device Indicator
			+	+	+	+	+	+	+	+
1) Detect/locate power system events	+	↑↑		↑↑		↑		↑		↑
2) Process Big Data	+	↑↑				↑↑				
3) Wireless communication	+	↓		↓	↑↑	↑			↓	
4) Easy to use	+		↑↑							↑
5) Meet IEEE.C37.118 standard	+	↑↑				↑	↑	↑		
6) Interactive multitouch display	+		↑↑						↑	↑
7) Event indicator light	+	↑	↑	↑↑		↑				↑↑
8) Solar Panel	+		↑					↑↑	↑↑	
9) Educate users about power system	+	↑	↑↑	↑↑			↑↑			
Targets for engineering requirements			At least 2 touch points	At most 5 seconds	2.4 GHz & 5 GHz band		60 Hz with at least 2 buses	100 W and at least 12 volts output	20 kg	

Figure 4: Engineering and Marketing Requirements HOQ

References

1. IEEE C37.118 Standard: https://standards.ieee.org/standard/C37_118_1-2011.html

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