UCF Senior Design I

Title: Machine Learning Applications in

Power System Fault Location with ADMS and AMI

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Initial Project Document and Group Identification

Divide and Conquer

<u>Group 11</u>

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1 Executive Summary

The objective of this project is to enhance the stability of the power system through the implementation of a machine learning model. By leveraging machine learning techniques to analyze large amounts of real-time data, a robust fault locator solution can effectively narrow down parameters, reducing restoration time, and improving overall efficiency for the utility industry. With real-time and on-demand measurements from ADMS (Advanced Distribution Management System) and AMI (Advanced Metering Infrastructure), the machine learning algorithms can process and reconsolidate grid data to accurately identify fault locations by measuring impedance using controlled currents. This enhanced fault location capability will facilitate expedited response times, leading to minimized downtime for customers and improved grid performance. The project will be implemented on a sophisticated 12-volt, single-phase microgrid hardware design, exemplifying a comprehensive understanding of fault detection and isolation methodologies. By intentionally inducing a short-to-ground scenario, the project aims to effectively demonstrate the fault location algorithm's capabilities within this intricate microgrid system. This project is based on a real-world problem raised by the utility industry. By combining machine learning technology with dynamic power system grid operation, this project’s impact extends beyond the development of a robust fault location solution using machine learning. This project could lead to more cutting-edge machine learning applications on the power grid, minimizing restoration time, and optimizing power system performance.

The real-time measurments from ADMS (advance Distribution Mangement System) provides telemetry on the substaion connecting tranmission and distribution system, topogies, and feeder. AMI (advance metering infrusture) and other intellegnt devices withi the power grid provides data at equiment level

ADMS is able to located the fault at the feeder level with the fuzzy sets of model the uncertainity in the fault location method.

2 Project Description

2.1 Project Background

(specific problem, the needs, and potential impact.)

This project aims to improve the stability of the distribution system by implementing a machine learning model to locate and isolate the fault location efficiently. Machine learning can observe and analyze the pattern of a dataset to identify any anomalies. With the large amount of real-time and offline measurements produced by wide-area measurement systems such as ADMS, the AMI system, and other intelligent electronic devices in the power grid. Not only are substantial amounts of data being fed into the machine learning algorithm all the time moreover the quality of the data in the power grid is also guaranteed because multiple data points make low-quality data easy to identify. This creates a perfect environment for machine learning to help with identifying outage patterns, prioritizing restoration efforts, and improving overall grid reliability. Manually monitoring can be slow and costly even with the help of smart devices and contingency alarms, machine learning enables real-time monitoring and predictive analysis, allowing grid operators to quickly locate the source of the fault and take proactive measures to prevent widespread outages.

This project is sponsored and funded by Florida Power and Light, they are responsible for all costs associated with materials, equipment, prototyping, etc. They will also provide additional resources or facilities needed for the project's successful completion. The sponsors provided this project idea because they noticed the growing trend of machine learning applications in the field of power grid operation, aiding in many areas such as outage forecasting, stability assessment, control, and restoration. This project focuses on the stability assessment aspect, aiming to evaluate transient stability, short-term voltage stability, and contingency screening. The sponsor wants an applicable machine learning algorithm capable of identifying and isolating faults down to individual meter levels, the restoration time can be shortened if the lineman knows the exact location of the fault instead of manually going through all the areas. This not only saves time and labor in terms of outage restoration, but the shorter restoration time will also help ensure customer satisfaction.

The two elements that will go into this project will be the machine learning algorithm and the hardware simulation demonstration. The algorithms will include data preprocessing, extracting, and learning features with the appropriate machine learning model, task class classification to detect and locate the fault, and alerting the system operator once the fault has been located. With the machine learning algorithm, we hope to be able to search the parameter for faults by comparing overall impedances from different injection sites to compute a geographical representation of the fault location. For three or more injection sites, multiple 2-dimensional matrices are needed to compute its exact location. High overall impedance indicates that the fault location is far away, and vice versa.

The hardware is a single phase one radical line small-scale distribution grid backed with real-world data supported by our PCB for demonstration purposes. It will use the power supplied in the GE-FPL microgrid control lab to power a series of passive components and switches. Protective devices such as fuses will be added for protection purposes and to help with measuring the sent-out voltage. By shorting one of the switches to ground, we will simulate a fault in an area. Once the machine learning algorithm is deployed it should be able to locate the feeder, the possible parameters within the feeder, and then the exact fault area. This design will simulate a one-line radical distribution grid, the second goal for this project is to be able to demonstrate a few branches to ensure the machine learning model is trained for different issues relating to various kinds of power grid design.

There are some equivalent products in terms of stability assessment with machine learning, in general, this idea is still new so many of the approaches have not been tested. A lot of useful data is being wasted because of the lack of fast data processing ability. And because we will be working with applications and data provided by the sponsor, we have the added challenge of converting data type into acceptable matrix form for our chosen machine learning model. The two applications our data come from are ADMS (advance distribution management system) and AMI (advance metering infrastructure). Data from ADMS is SCADA (Supervisory Control and Data Acquisition) based, it will give clarity by gathering real-time data from sensors and devices located throughout the power grid infrastructure for faults in the feeder level. This data updates every 30 seconds to 1 minute. This data includes information on real, reactive, and apparent power, voltage levels, current flow, transformer status, breaker positions, and other operational parameters. This is the most popular telemetry collection and analysis system that provides the operator with the alarm once a contingency is detected at the feeder level. ADMS also provides a map of all nearby substations and power lines so we can gaze far out from where the fault might be located and how it is impacting the adjusting area. AMI is a two-way communication system to collect detailed metering information, typically AMI data normally updates every 15 to 30 minutes and can be requested if needed. AMI measurements extend beyond the feeder level down to the equipment level, they can provide data attached to every customer's meter and solar panels. This data includes information on Cumulative and daily kWh usage, peak kW demand, load voltage profile, and power factor. AMI data are often underutilized due to their high volume and too much information makes them different to be sorted out.

Our PCB design will consist of an MCU with built-in flash memory. Based on the data we capture from ADMS, we will train our model and then flash it onto the MCU. The PCB will be responsible for determining the geographic location of a fault as well as isolating said fault. To do this, we will have several injection sites along the distribution grid that will measure the impedance across their connected lines, forming a matrix of impedances with their associated weights. This matrix of impedances will be compared to our Machine Learning model to determine the presence of a fault. A visual representation is shown later in Figure 4, take note of the four injection sites and the fault on one of the branches. Locating the fault would consist of taking the weights of all four sites, sites 1 and 2 would have a lower weight due to their proximity. While site 3 and 4 will have higher weights due to their distance. A representation of the impedance matrix is shown in the figure below.

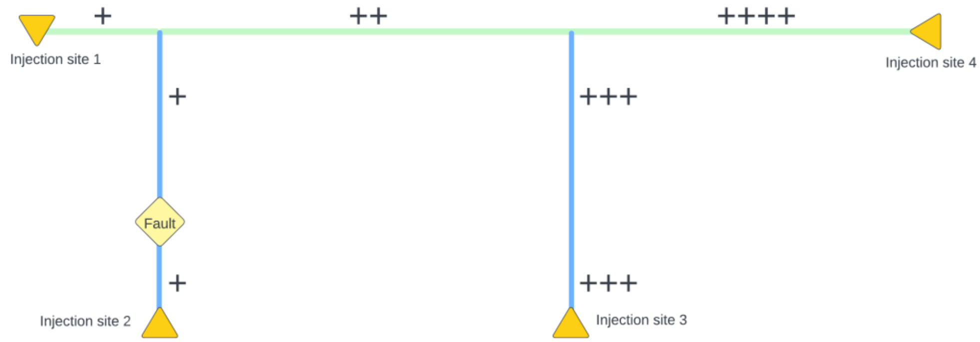


Figure 1: Visualization of impedance matrix with weighing

This project is unique because it is based on a real-world issue that could potentially impact half 60% of Florida residents and businesses. We are motivated to work on a project that utilizes machine learning to locate faults on power lines and reduce restoration time because we believe in the transformative potential of advanced technologies in improving the reliability and efficiency of power grids. Every home and commercial and industrial center in America is backed by the power grid, by applying machine learning algorithms to analyze data and identify fault locations accurately we hope to improve the overall stability of the power grid and shorter restoration time. UCF's Power and Renewable Energy Program boasts a highly dedicated and diverse faculty with exceptional backgrounds, all deeply passionate about power systems and committed to student success. Moreover, this program provides access to state-of-the-art equipment and ample mentoring opportunities, ensuring students have the necessary resources to excel in their studies. With the help of the combination of knowledgeable professors, a supportive environment, and abundant mentorship we hope this project can solve a real-world issue.

2.2 List of Requirements and Specifications

Table 1: Requirements and Specifications

No.	Requirement	Specification	Description	Priority
1	Fault Detection	Less than 30 minutes	The time the system takes to detect and identify the location of a fault must be within 30 minutes.	High
2	Fault Location Assessment	Within a mile of the actual fault location	Models' detection algorithm must be able to provide a location for the fault with an error of less than a mile	High

No.	Requirement	Specification	Description	Priority
3	Water/Weather Resistance	IPX6 and IP5X Water/Particulate rating	Must be able to withstand being outside or buried underground.	High
4	PCB Communication	USB to serial UART	PCB must be able to connect to a computer to retrain or debug machine learning model.	High
6	Impedance Matrix Calculations	Able to calculate with 4 or more signals	The model must be able to accurately process impedance values from at least 4 injection sites and weigh them against each other to determine fault location.	Med

2.3 Project Block Diagram

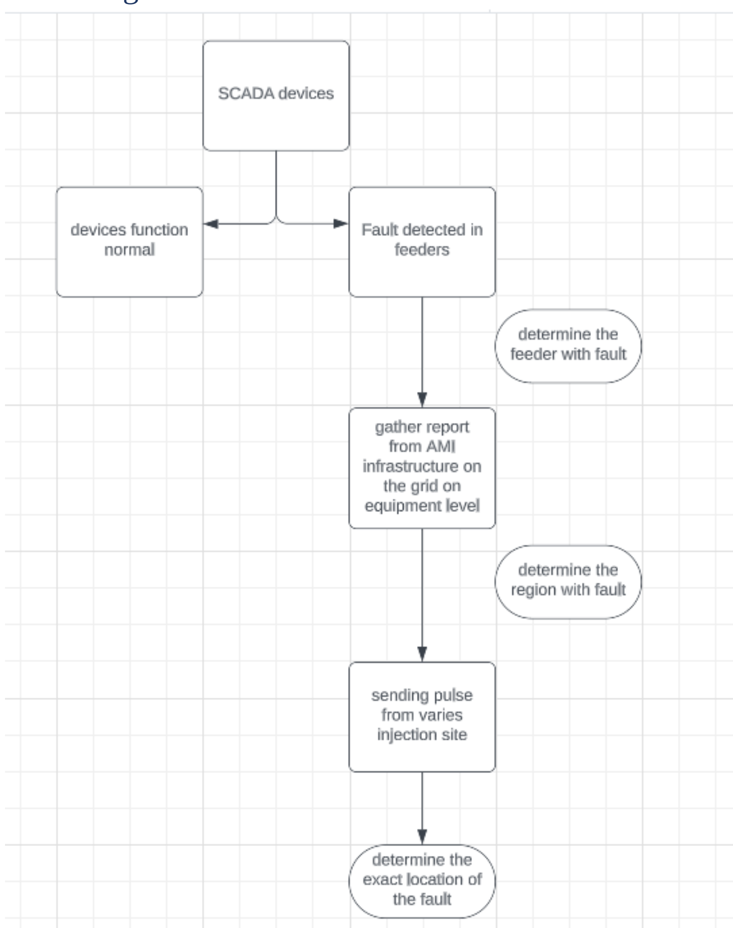


Figure 2: high level overall flowchart

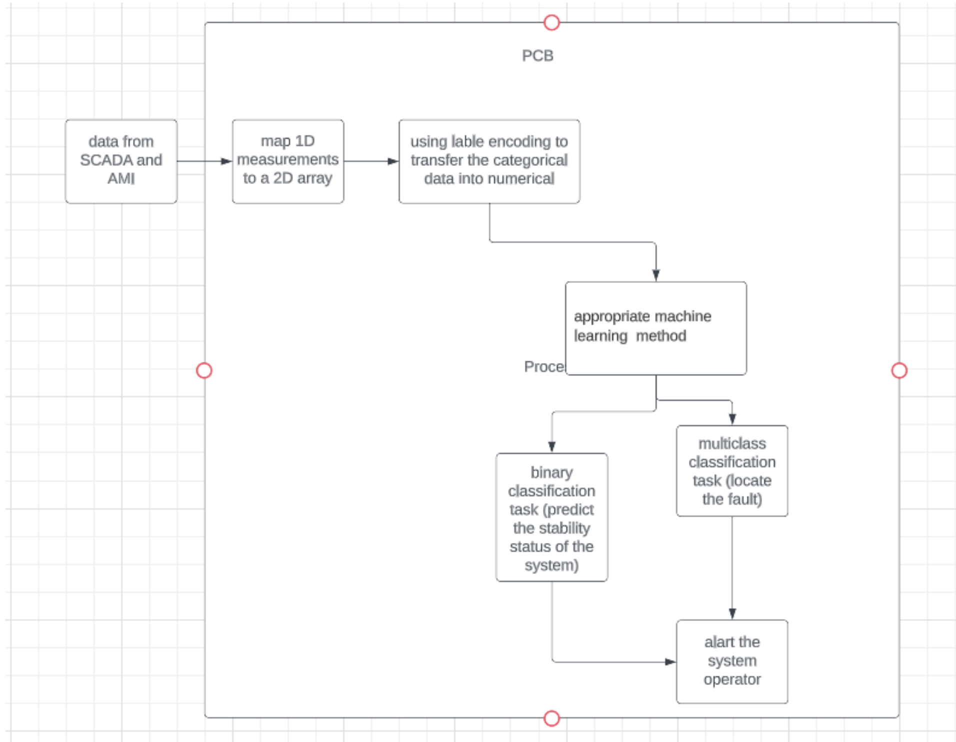


Figure 3: Flowchart of the proposed ML model

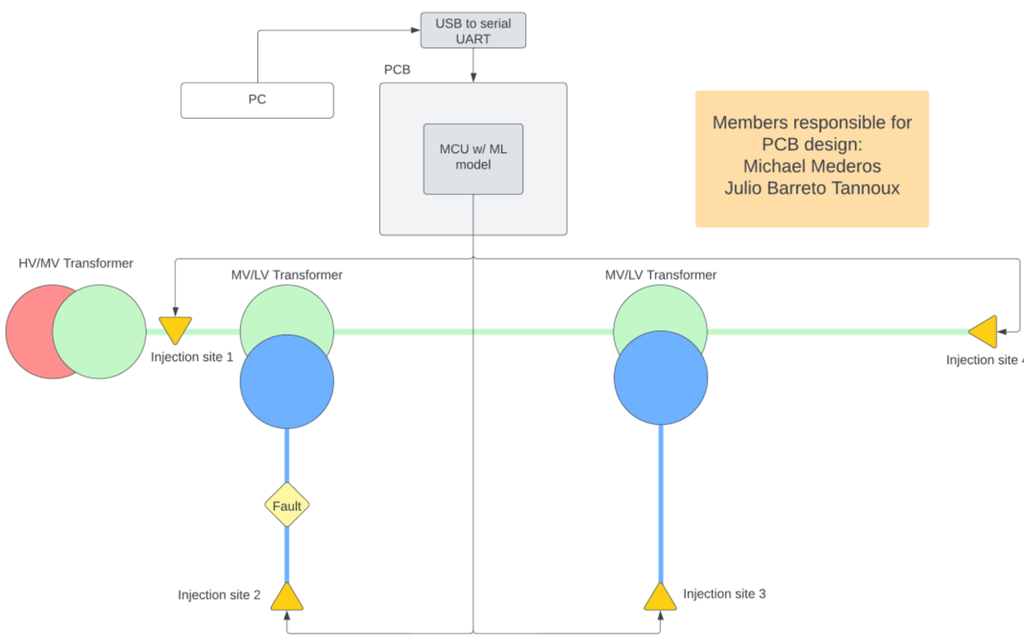


Figure 4: Block diagram of PCB interaction with grid

2.4 Project Budget and Financing

The budget for this project will be divided into parts for assembling the printed circuit board (PCB) and any other components needed to get the physical simulation running. Some items needed for the PCB will be passive components like resistors and capacitors, a timer and clock system, a power module, OP-AMPs for the power source schematic, and a stepdown transformer so that the system can be powered through a wall outlet. To reduce costs, a timer that can also function as a clock is likely to be used in the PCB design.

As part of FPL's partnership with this project, FPL will cover the costs of the project. Even with help from an outside source, we want to find a balance of minimizing the product costs while still providing an effective product. Also, some of the equipment that will be used in the hardware simulation will be provided by the UCF lab. Examples of this provided equipment will be passive components like resistors and capacitors as well as the cable that will be used to simulate our feeder and lateral systems.

Table 2: Prototype Budget

Item Description	Quantity	Total Estimated Cost
Microcontroller	1	$3-10
Printed Circuit Board (PCB)	1	$50-300
Passive Components	20-30	Provided by Lab
Cable for Simulated Grid	50	Provided by Lab
Timer for Printed Circuit Board	1	$5-10
Power module for Printed Circuit Board	1	$10-15
OP-AMPs for Printed Circuit Board	2	$2-4
Switches for Short Circuit Simulation	3-5	$36-60
120V/12V Step Down Transformer	1	$10-35
	Total:	~$116-434

2.5 Project Milestones

In order to be able to accomplish our goals, we set a few milestones so we can keep good track of the project development. This way we can also ensure that we will meet the final deadlines for the report and presentation. Also, the chart shows the responsibilities of each member of the group so everyone can get a fair share of work and contribution.

Table 3: Project Milestones

Week	Date	Task	Status	Responsible
Planning				
1	5/29	Brainstorm	Completed	Group
		Choose Project	Completed	Group
	6/02	Divide & Conquer paper	Completed	Group
2	6/05	Meeting with advisor	Complete	Group
Research				
3	6/12	Research Dyno Net ML algorithm	On Track	Michael
		Determine I/O model for algorithm	On Track	Group
		Understand ADMS and AMI	On Track	Group
4	6/19	Impedance injection/detection	On Track	Group
		PCB System Requirements	On Track	Michael/Julio
		MCU requirements for ML model	On Track	Michael
5	6/26	Import real world data from ADMS and AMI	On Track	Yuejun
	6/30	60-page draft documentation	On Track	Group

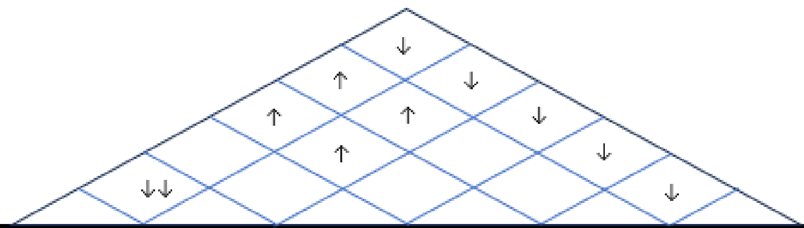
Design & Order				
6	7/03	Build schematic	On Track	Michael / Julio
		BoM	On Track	David
7	7/10	Order parts	On Track	Group
8	7/17	Write ML model	On Track	Michael
		Connect I/O model to our ML model	On Track	Group
9	7/24	Document review	On Track	Group
	7/25	Final 120-page document	On Track	Group
Prototyping & testing				
10	7/31	Test components & code	On Track	Group
11	8/07			
12	8/14			
13	8/21	Breadboard testing	On Track	Group
14	8/28			
15	9/04			
16	9/11	Design & Order PCB	On Track	Group
17	9/18	Flash & Train ML model	On Track	Group
18	9/25	Debug/Refine model	On Track	Group
19	10/02			
20	10/09	Build grid representation	On Track	Group
21	10/16	Testing & Redesign	On Track	Group
22	10/23			
23	10/30			

Final Details				
24	11/06	Finalize prototype	On Track	Group
25	11/13			
26	11/20	Peer Presentation	TBA	Group
27	11/27	Final Report	TBA	Group
28	12/04	Final Presentation	TBA	Group

2.6 House of Quality

In the following chart (figure 5), we were able to visually depict the correlation between the engineer requirements with themselves and with the market requirements. Our project is supposed to be used and installed by professionals, it doesn't have to be very easy to install or understand since those that are going to work with it will possess the necessary skills and knowledge to operate it. Mostly the market requirements are based on how much it improves the process of finding a fault in the electric system and fix it. The faster and more precise our device, the better. Upward and downward arrows simbolize wether there is a positive or negative correlation respectively. And if there are two arrows, it means that there is a strong correlation.

Figure 6 shows more clearly the engineering requirement trade off, that is also seen in the roof of the House of Quality.



	Fault Detection (-)	Fault Location Assesment (-)	Water / Weather Resistance (+)	PCB Communication (+)	Impedeance Matrix (+)	Cost (-)
Grid Stability & Reliability (+)	↑↑	↑↑			↑	↓
Time to find fault (-)	↑↑	↓		↑	↑	↓
Precise location(+)	↓	↑↑		↑	↑↑	↓
Restoration times (-)	↑	↑	↑		↑	↓
Cost (-)	↓		↓		↑↑	↑↑
Targets	< 30 min	< 1 mile	IPX5 or IPX6	USB to UART	>= 4 Signals	<= $434.00

Figure 5: House of Quality

	Fault Detection (-)	Fault Location Assesment (-)	Water / Weather Resistance (+)	PCB Communication (+)	Impedeance Matrix (+)	Cost (-)
Fault Detection (-)		↓↓		↑	↑	↓
Fault Location Assesment (-)				↑	↑	↓
Water / Weather Resistance (+)						↓
PCB Communication (+)						↓
Impedeance Matrix (+)						↓
Cost (-)						

Figure 6: Engineering trade off matrix