3 Design

3.1 Design Context

3.1.1 Broader Context

Describe the broader context in which your design problem is situated. What communities are you designing for? What communities are affected by your design? What societal needs does your project address?

List relevant considerations related to your project in each of the following areas:

Area	Description	Examples
Public health, safety, and welfare	This project will aid in providing consistent power to those who need it. Will ensure that services and safety depending on reliable energy will indeed get that energy safely.	Hospitals will get the power they need to ensure they can provide healthcare as normal. Water plants will be able to process water as normal.
Global, cultural, and social	Infrastructure in areas of the world where consistent power delivery may not be the norm would be affected by this project.	If a transmission line goes down in a grid, it would help pin-point where the faulty line is and what kind of problem may have occurred. Helping get the grid back and running as quickly as possible.
Environmental	Being able to determine where a fault is occurring and what kind of fault is occurring. Being able to shut off the transmission of power when a fault occurs so there isn't any power loss to ground so there isn't any waste of the resources used to generate power.	Our product should decrease the amount of energy lost when a fault occurs in a transmission line. This will then reduce the amount of production of energy to make up for the energy lost. This will then save the transmission company's money which may then get used to convert away from nonrenewable resources.
Economic	If transmission utility companies can save the amount of power that's lost due to faults then they won't be losing money from the loss of power. This will then make it so the price to have electricity won't increase for the consumers.	Since our project is mostly software oriented and doesn't have many hardware requirements it will be very affordable since it shouldn't cost really anything for the target users. It will also reduce the amount of energy lost in a fault which will save the target users money since they won't be wasting the energy they are producing.

3.1.2 User Needs

The transmission utility companies need a way to quickly shut off the power going through transmission lines and detect a fault because they don't want to waste any power by sending it to ground and want to be able to fix the issue as soon as possible.

3.1.3 Prior Work/Solutions

Include relevant background/literature review for the project

– If similar products exist in the market, describe what has already been done

Fault detectors already exist, though they detect faults by measuring resistance on the line.

– If you are following previous work, cite that and discuss the advantages/shortcomings

n/a

– Note that while you are not expected to "compete" with other existing products / research groups, you should be able to differentiate your project from what is available. Thus, provide a list of pros and cons of your target solution compared to all other related products/systems.

	Current Method	Our Method
Fault Detection	Measures line resistance	Uses neural network to compare waveforms
Fault Analysis	Can only tell if **a** fault occurred	Can tell if a fault occurs, and what type of fault
Fault Location	"Rough idea" of where fault is located	Pinpoint where the fault is along the line (with 98% accuracy)

Detail any similar products or research done on this topic previously. Please cite your sources and include them in your references. All figures must be captioned and referenced in your text.

3.1.4 Technical Complexity

Provide evidence that your project is of sufficient technical complexity. Use the following metric or argue for one of your own. Justify your statements (e.g., list the components/subsystems and describe the applicable scientific, mathematical, or engineering principles)

1. The design consists of multiple components/subsystems that each utilize distinct scientific, mathematical, or engineering principles –AND–
2. The problem scope contains multiple challenging requirements that match or exceed current solutions or industry standards.

Components/subsystems: This project will require the building and tuning of a transmission system model that accurately portrays a real world situation and problems that may occur. This overall system will consist of power electronics, generators, loads, and different transmission lines. To properly implement this system we will need to have understanding of power systems analysis, circuit design, knowledge of how to account for transients in large cables, and feedback systems.

Another system we will have to implement is a neural network which will handle signal and data analysis to determine if and where a fault is occurring. The neural network will have to implement coding standards, extensive power systems analytical equations, and understanding of machine learning.

Problem Scope: This problem will eventually be better and faster than industry standards for fault detection and better able to pinpoint a location and nature of a fault which is occurring. We aim to be able to detect faults quicker and with greater precision.

3.2 Design Exploration

3.2.1 Design Decisions

List key design decisions (at least three) that you have made or will need to make in relation to your proposed solution. These can include, but are not limited to, materials, subsystems, physical components, sensors/chips/devices, physical layout, features, etc.

1. The first key design decision is what criteria we will use to train the neural network to properly detect faults and where they happen. Due to the nature of the data we will need to work with, much of this will rely on how we use the voltage and current in the three-phase system to determine if there is a fault, where it is happening, and if we should trip the line.
2. The second key design decision that has been made is the type of neural network we will be making. As decided by the client and advisor, we will be creating a Long Short-Term Memory neural network that will take in the current and voltage over a section of time and decide if there is a fault, where the fault is occurring, what type of fault there is, and if the circuit should trip.
3. The third key design decision that will need to be made is the sample size of the data. This decision will depend on the consistency of the simulation data we retrieve and all the points we wish to test within our simulated system. Based on where we want to test faults, what faults will occur, the voltage and current of the system, how long the lines will be, and how many times we feel we need to run the simulation will determine how much data we will be using to train our AI.

3.2.2 Ideation

For one design decision, describe how you ideated or identified potential options (e.g., lotus blossom technique). List at least five options that you considered.

In reference to training of the neural network we will need to determine some key things.

1. How many faults to feed our system.
2. How many sets of data to give our neural network to work with.
3. How quickly we should determine a fault or not
4. How to determine which breaker is opened based on distance calculations
5. Coding method and neural network type to use.

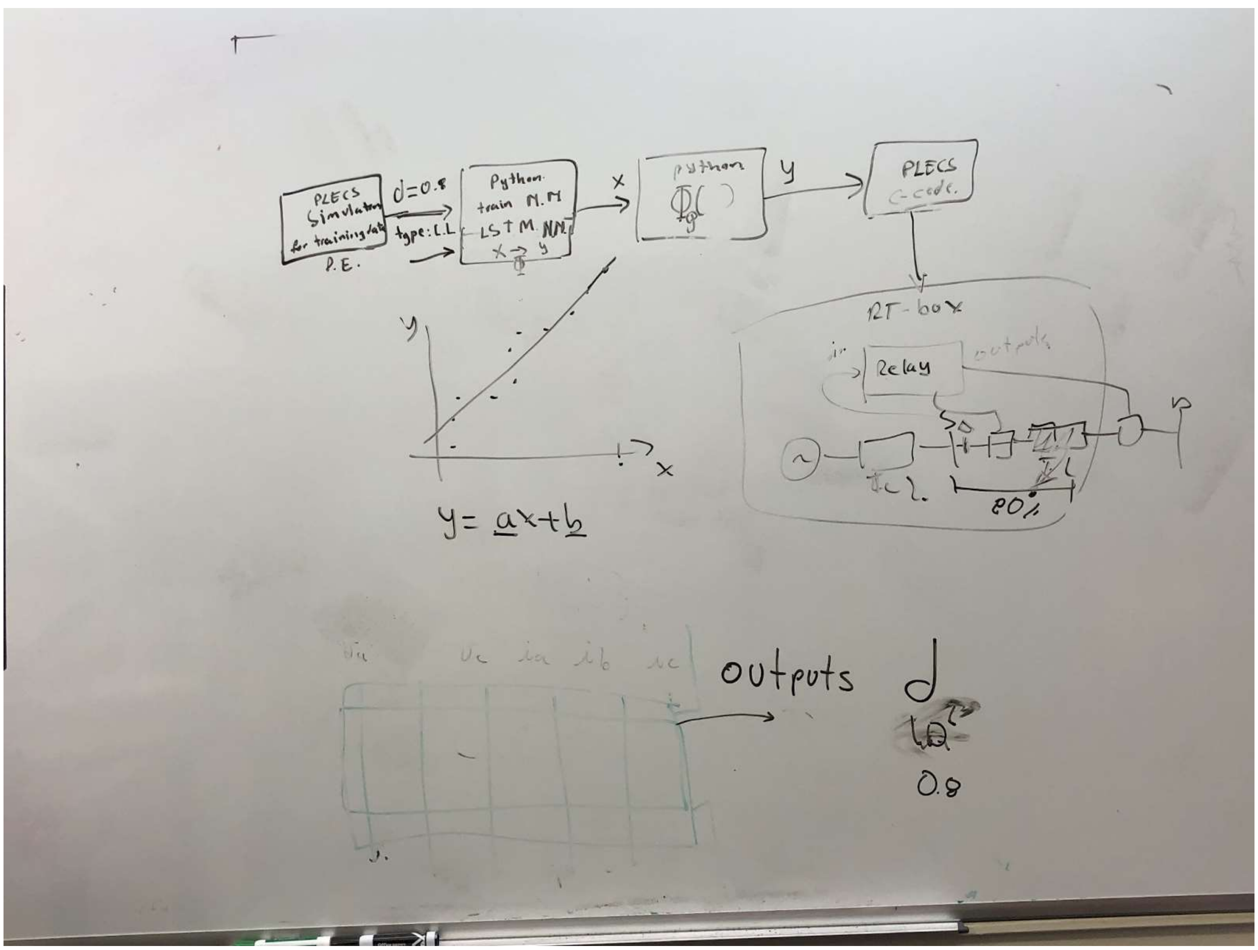
3.2.3 Decision-Making and Trade-Off

For how many faults fed into the system we have determined to do all the possibilities rather than leave any potential faults out. For how many datasets we have determined that giving around 10 would both be most efficient and accurate as well. For how quickly we should determine a fault we are given a minimum of 2 Hz to determine a fault and may increase how quickly we detect a fault should our system work correctly. For determining which breaker should open we will use per-unitized distance calculations as opposed to looking at every line simultaneously to increase speed and accuracy of system. For the coding method we will use agile as it is quicker and easier to do as a team in comparison to waterfall methods.

3.3 Proposed Design

So far in our project, we have been able to do various test runs for our fault detections. We are confident in knowing what a specific fault looks like through our PLECS models results. We also have gotten a good understanding of which steps to take towards our goals and in which order to perform them. Anthony has also done some playing around with the software coding to perform these PLECS tests at a rapid rate and output files of the results. This will later be used for our input into the neural network.

3.3.1 Design Visual and Description



Our current method involves us creating a simulation in PLECS with all the appropriate simulink-like components. From here, we can use Python to train a neural network - of which we have several options - to identify the fault and produce a function that will take the waveforms as inputs and derive an output. With this output, we can determine the best course of action that should be taken (ie. open or close the circuit breaker). Once we have this function, we can plug it into a C-code to use in PLECS. Running the model should then produce the results we have been looking for.

3.3.2 Functionality

Our design will operate in the real-world by being attached to a transmission line of some length. This small box is meant to be attached with a CT to read the voltage and current waveforms. It will then look at the data that it is fed to teach itself when to open the breaker that it is connected to. A visual is supplied in the image above.

The current design would satisfy all requirements by being able to open a circuit breaker if a fault is detected.

3.3.3 Areas of Concern and Development

Our current concern with this project is being able to produce an accurate function that will detect when a fault has occurred in the line. This is a complex problem that involves many different parts that must work together in order to correctly operate. If one thing goes wrong, the product may not operate correctly.

Other concerns with that would be producing false positive results. This could skew our data and thus our function would not be as accurate and would not operate correctly.

To lessen this concern, we are actively reviewing our constraints and going over how neural networks operate extensively. We have asked questions to our advisor and been able to kind of get a mild understanding of how these things work.