Automatic Design of Distance Protection

Design Document

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Executive Summary

Development Standards & Practices Used

The practices used in this project include PLECS, C - programming, a real-time simulator, and Python.

The engineering standards that we are using for consideration in this project include Instrumentation and Measurement, National Electrical Safety Code (NESC), FERC/NERC Compliant, Power and Energy, Power Electronics, Smart Grid, Software and Systems Engineering

Summary of Requirements

● 30 ms response time for detecting fault

● Where on a transmission line/network a fault is occurring

● What type of fault is occurring on the line (e.g. Line-to-line, line to ground, etc.)

● Response to fault in the transmission line by opening or closing a circuit breaker.

- We are not to use impedance calculations and are instead going to analyse the waveforms through the use of a neural network.

Applicable Courses from Iowa State University Curriculum

EE303, EE456, EE324, EE201/230, EE311/411x

New Skills/Knowledge acquired that was not taught in courses

Python Coding, Machine Learning Design, Team Building & Collaboration

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Definitions:

Fault- Any sudden unexpected change in current. Often pertaining to power delivery.

Neural Network- A neural network is a series of algorithms that endeavors to recognize underlying relationships in a set of data through a process that mimics the way the human brain operates. In this sense, neural networks refer to systems of neurons, either organic or artificial in nature.

Machine Learning- Machine learning is the study of computer algorithms that can improve automatically through experience and by the use of data.

Transmission System- A system in which large amounts of power are transmitted across a distance using conductive wires - typically very high voltage.

1 Team

1.1 Team Members

Matthew Dobrzynski, Taylor Semple, Chye Stecher, Anthony Ruffalo, Keegan Kraft, Josh Vrenick

1.2 Required Skill Sets for Your Project

PLECS Modeling Skills, Mathematics, Power Systems analysis, RT box skills, Python & C coding skills, teamwork and communication skills, circuit designs skills, GIT LAB skills.

1.3 Skill Sets covered by the Team

Power systems analysis: Matthew, Taylor, Keegan, Chye, Josh
Python coding: Anthony, Matthew, Keegan, Taylor
Software Architecture: Anthony, Matthew
Matlab/simulink: Matthew, Taylor, Chye, Keegan, Josh
Circuit Design: Matthew, Taylor, Chye, Keegan, Josh

1.4 Project Management Style Adopted by the team

Agile – developers (any technical work that you do incl PCB design),
scrum master (the leader who keeps you on schedule and interfaces with the client), product owner (client who states if a product is acceptable)

1.5 Initial Project Management Roles

Developers: Matthew, Anthony, Chye, Keegan, Josh, Taylor
Scrum master: Taylor
Product owner: Matthew

2 Introduction

2.1 Problem Statement

Fault detection systems are crucial to transmission systems as the faster we can respond to and kill the power to a faulted line, the more outages and damages we can minimize. Our solution to this will be a neural network that can detect these faults by the change in voltage and current waveforms. Also, to make fixing the fault faster our solution will be able to tell where on the line the fault is and the type of fault that is occurring - ie. a line touching the ground or a line touching another.

2.2 Requirements & Constraints

Quantitative-

- 30 ms response time for detecting fault
- Where is the fault located along the transmission line in reference to the sending end of the line.
- What type of fault is preset - line to line, line to ground, etc.
- Response to fault in the transmission line - ie 1 or 0 to open or keep the breaker closed.

Qualitative-

- We are not to use impedance calculations and are instead going to analyse the waveforms through the use of a neural network.

2.3 Engineering Standards

Instrumentation and Measurement - We will need to follow this standard to get accurate readings of our waveforms and be able to interpret them to find our fault somewhere on the line.

National Electrical Safety Code (NESC) - Following the NESC code makes sure that our design is safe and effective at all times.

FERC/NERC Compliant - We follow this one to maintain legality and federal operating conditions of our network (ie. Make sure the money keeps flowing).

Power and Energy - We should follow all standards in the IEEE category of P&E in order to keep safety at the forefront of this project.

Power Electronics - We shall be modeling the use of power electronics which will control the flow of current and voltage through transmission lines. We will need to follow the engineering standards associated with power electronics.

Smart Grid - We will be implementing fault detection in a grid which will be able to determine where in the grid the transmission lines are failing. Being able to determine which power electronics to activate.

Software and Systems Engineering - We will need to use this standard to make sure our software for the neural network is made and functions properly.

2.4 Intended Users and Uses

Benefits the electrical company money since it detects the fault faster and trips a breaker so they aren't pushing power into the ground and will not damage any power electronics

Benefits consumers so that they receive the power they are expecting

Land owners and environmental activists will benefit since the system will set a breaker to turn the line off faster so their land doesn't catch fire and harm the environment.

3 Project Plan

3.1 Project Management/Tracking Procedures

We have chosen to use the Agile methodology, as we are working alongside our client rather than for our client. Most of our project goals are appearing as we meet with our client and come up with some information for him.

Our group has decided to use Discord, Google Docs, and GitLab to track our progress throughout the course.

3.2 Task Decomposition

1. Simulate a judicious transmission system for distance protection studies in PLECS
    a. Build model which accurately portrays a real-world transmission system
    b. Adjust settings and nature of faults to gain different sets of data for robustness
2. Frame mathematically the design constraints for distance protection to define a reward function for reinforcement learning
    a. Gaining data which features each set of faults that could occur in our transmission system.
    b. Development of exporting data from PLECS to python in some efficient fashion
    c. Open circuit breakers based on numerical analysis of faults that occur.
3. Design and execute a reinforcement learning environment that interfaces with PLECS
    a. Development of a neural network which may take a set of data and determine characteristics of the faults that occur in our transmission system.
    b. transporting data from PLECS to python and back to PLECS for controlling of the system
4. Implement the controller from reinforcement in a real-time simulation environment, i.e., in the RT box.
    a. Learn how to implement the RT-box with our model in order to get a real-world example of how our system would function.
    b. Collect data and adjust our model/ideas to accurately deal with the results coming from using the RT-box

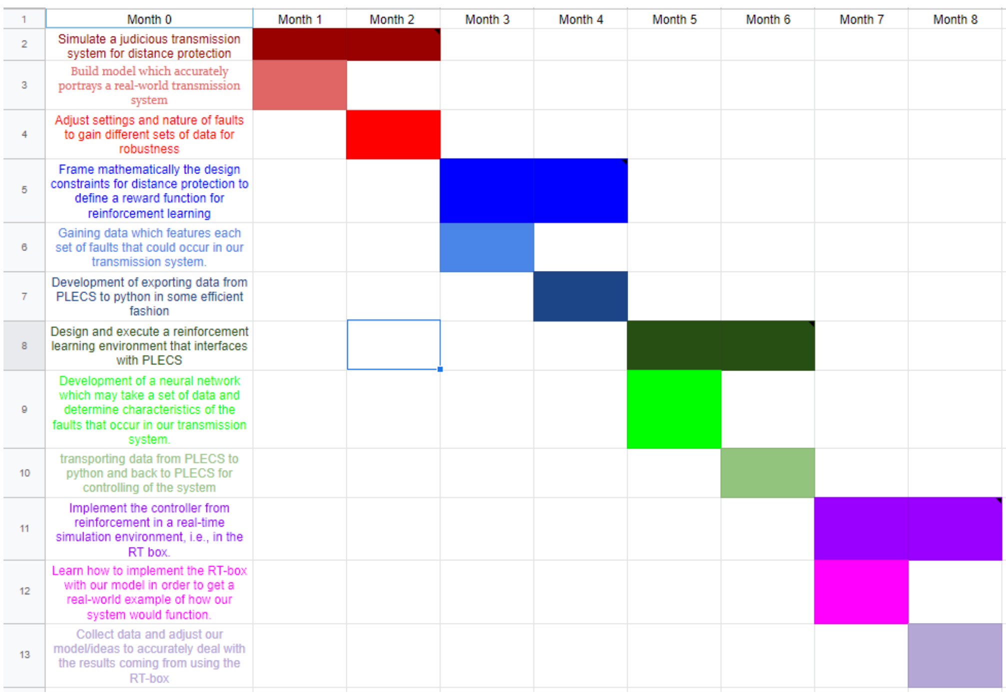
3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

1. Simulation model - Measurement of progress would be if this is complete with all aspects taken into account.
    a. Our model should be able to simulate a fault occurrence at some point in the line with a decent amount of accuracy (>75%).
    b. The model should also be able to detect that a fault has occurred with near perfect accuracy (>90%).

2. Mathematical model of a reward function - Measurement of progress would be if this is complete and able to detect a fault.
    a. Our mathematical model should be able to detect a fault with 75% accuracy.
3. Script for reinforcement learning - Measurement of progress would be if this is complete and is able to detect a fault and open the circuit breaker.
    a. The script should be accurately determining if a fault is present and decide what to do in the instance of a fault (>50%).
4. Final proof of concept while using a real-time simulator - Measurement of progress would be if this is complete and works around 80% of the time correctly.
    a. The model and final proof should be able to accurately find that a fault is occurring and determine what type. This should also be able to de-energize the line and give a rough estimate of the distance at which the fault occurred. This should be around >80% accurate.

3.4 Project Timeline/Schedule

Figure 1: Gantt Chart



3.5 Risks And Risk Management/Mitigation

Risks that we may run into include…

- PLECS components don't run or work as intended which then skews our data and give us incorrect information
- Model developed in PLECS does not interface sufficiently with RT-box and gives erroneous data/results.
- There is some internal issue, or malfunction, that occurs with the RT box that isn't obvious and interferes with our real-time simulation.

- Mitigation for this would be…for any issue with the RT-box, we shall feed in control cases to get a baseline for how the RT box is functioning as well as any adjustments that need to be made.

3.6 Personnel Effort Requirements

Table 1: Personnel Effort Requirements

Task	Reference/explanation	Estimate (person-hours)
Simulation model	Reference: We have spent around 3 hours running each of our faults. Explanation: This will include each of the faults, but will need much more data for our program.	10-20 hours
Mathematical model of a reward function	Reference: This is also based on the time we have spent in PLECS up to this point. Explanation: This will include the execution of the fault detection, not the data we collected to find it.	5-10 hours
Script for reinforcement learning	Reference: This is based on our overall knowledge of Python and what it will take to complete. Explanation: This will include the initial simulation model, and our AI system that will execute the location of the fault.	20-30 hours
Final proof of concept while using a real-time simulator	Reference: We do not have a current reference because of where we are in the project and do not have any prior knowledge using this. Explanation: This will include the final simulation and testing our fault location system.	10-20 hours

3.7 Other Resource Requirements

Other resources that we will need to use for our project will include a RT box that will run our simulations in real time. We will also need to use Python to run and examine our testing from our PLECS outputs, which is another resource that we are using.

4 Design

4.1 Design Context

4.1.1 Broader Context

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

Table 2: Broader Context of Our Project

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.

4.1.2 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.

4.1.3 Prior Work/Solutions

Similar designs for fault detectors already exist, though they detect faults by measuring resistance on the line. Whereas our product would be using the direct waveforms that are measured on the line at some point.

There is also no previous work on our project. Our project should be seen as a "proof of concept", because there are no current solutions using changes in waveforms to detect faults. Due to this, we have no preliminary data for which to test this idea or any of its offshoots. This could make for either a good situation, or a bad one. On one hand, we are free to develop the constraints as we see them and work through situations that may arise. On the other hand, some situations may prove to be quite troublesome and harder to solve. Nevertheless, we should be able to work with the current solution to try and develop a new one to the best of our ability.

Here is a simple table describing the differences between our solution and current solutions.

Table 3: Our Project vs Current Solutions

	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)

4.1.4 Technical Complexity

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.

4.2 Design Exploration

4.2.1 Design Decisions

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.

4.2.2 Ideation

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.

4.2.3 Decision-Making and Trade-Off

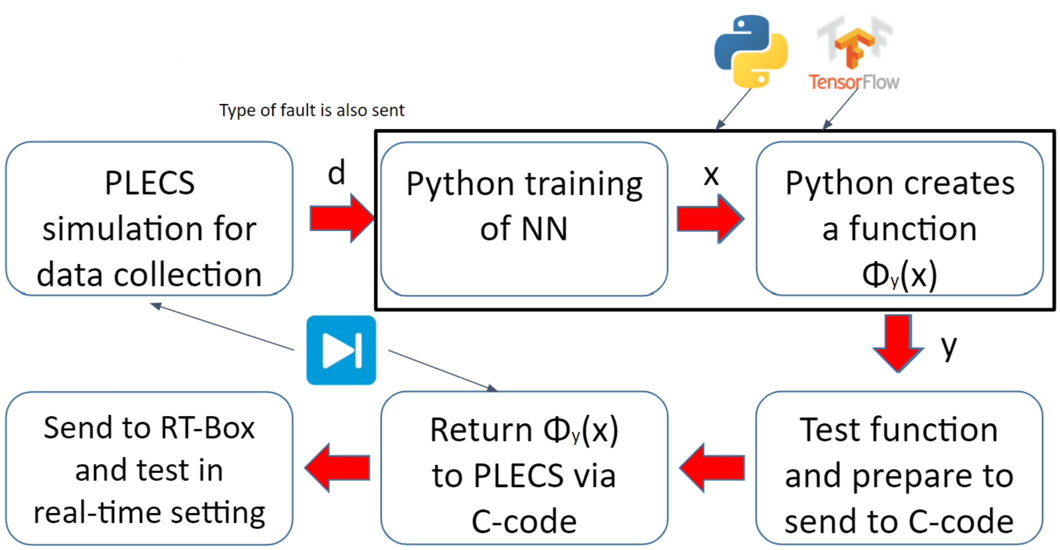
For how many faults fed into the system we have determined to do all the possibilities rather than leave any potential faults out. For how many datasets we have determined that giving around 10 would both be most efficient and accurate as well. For how quickly we should determine a fault we are given 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 the 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.

4.3 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.

4.3.1 Design Visual and Description

Figure 2: Design Flow Chart



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.

4.3.2 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.

4.3.3 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.

4.4 Technology Considerations

A strength that we have had within this project include our PLECS model, which includes the model of our transmission system (source, transformer, transmission lines, faults, breakers). This is because without this, we would not be able to obtain the accurate and desired voltage and current waveforms for our testings. These are then used in our neural networks' decision to open the breakers.

A weakness that we have found within this project is that tensorflow (our software storage for machine learning) may not be compatible with our neural network. A possible solution to this would be to use similar software storages that we will find to be compatible as there are many others available to us.

A weakness/trade-off that is included in this project is that it may be necessary to create multiple neural networks as it will be used for individual faults and decisions to open the breakers within them. This can be traded off from using one individual neural network that could be large and complex, potentially creating more errors and discrepancies.

4.5 Design Analysis

Thus far in the semester, we have been able to successfully complete our proposed design. This is in respect to where we are currently at in our project, which is working on the neural network to analyze our many outputs from our models. This has worked properly for us because of the ability to determine proper waveforms for our faults, and using a program to continuously run the modeled faults to collect as much test result data as we can. This will allow us to have a more accurate and dependable product.

Depending on the observations we make during the design process we may need to modify the system we are testing or the way our logic is driven through the circuit breakers in PLECS. We will more than likely need to adjust the neural network to ensure that it develops a function which works as needed.

4.6 Design Plan

Our design will work with the backbone being a neural network that is trainable to detect faults within our transmission system. We will first have to create a transmission system which simulates a real world environment.

Next we must collect data from the model to train our neural network and develop a function which will drive logic for a circuit breaker within our system. Then we will need to develop the logic and mesh it with the transmission system. We will need to be able to drive this logic within 30 ms of encountering a fault and determine which fault occurred.

Lastly we will need to be able to calculate the distance a fault occurs from a specified circuit breaker to determine if the circuit breaker should open or not. We will test this by placing faults at different points within the system and ensuring that the distance is calculated correctly. We are aiming to be able to accurately determine the location of a fault within a couple of miles. .

We will test these all to ensure that they perform as expected and required by our client and provide the best possible design.

5 Testing

Testing is an **extremely** important component of most projects, whether it involves a circuit, a process, power system, or software.

The testing plan should connect the requirements and the design to the adopting test strategy and instruments. In this overarching introduction, given an overview of the testing strategy. Emphasize any unique challenges to testing for your system/design.

5.1 Unit Testing

Using PLECS and the PLECS Model our team advisor gave us we are to collect current and voltage waveforms. The given PLECS Model allows us to export these waveforms as excel files.

5.2 Interface Testing

Our current PLECS Model is a block diagram of a mini power grind with an emphasis on having multiple transmission lines set up.PLECS allows us to add in a "fault block" that can simulate the different types of faults along the transmission line. When done properly the user can see the effect on the voltage and current waveforms through the output within their respective graphs.

5.3 Integration Testing

Our integration paths are going to be our RT Box sending a signal to our PLECS model which then feeds data to a csv file that our python code will be able to use to determine if there is a fault in the signal. To test that the RT Box is properly sending a signal to PLECS we can make a basic model that shows us the signal being used in PLECS and if it matches what the RT Box is sending. Then, to make sure the PLECS model is sending the correct information to the csv file we will just have to use analysis tools in PLECS to make sure the information in PLECS matches what is on the csv file. Finally, to test the python code, we would run the whole project together and if it can accurately detect faults then we know that our python code is running properly and our project can detect faults.

5.4 System Testing

As for the unit tests, we will be testing the specific faults, their detection, and the circuit breaker switch. As for interface testing, we will need to test between PLECS, python, C, excel, and our real-time simulator (RT box). Our integration tests will include the final runs of our testing. This will include all of our softwares coordination of the C code into the real-time simulator with the data that we previously collected from PLECS. Other than our previously stated platforms of softwares, we will be using an RT box as a tool.

5.5 Regression Testing

To ensure new additions will not break the system, the neural network will be hosted on the GitLab repository. As we add new changes and features, we will commit and push them to the version control software. Each of these commits represent a version of the program that we can return to and work from at a later point if we feel the current direction is not working. To make sure our main product is working properly, we will use branches to work on larger features before merging them into the main branch once they are finished.

5.6 Acceptance Testing

We will ensure that our design is meeting the specified time requirements as well as perform as it is expected to by repetitive testing and ensuring that time constraints and results are not being missed. Accurate distance detection should also occur and be calculated correctly with multiple sets of data being fed to the neural network. We will test all different scenarios and ensure that the testing done for each scenario is performing as satisfactory. We will involve our client by running them through the data and double checking that the system is performing as expected as set by the client.

5.7 Security Testing (if applicable)

This section does not apply to our current project at this time.

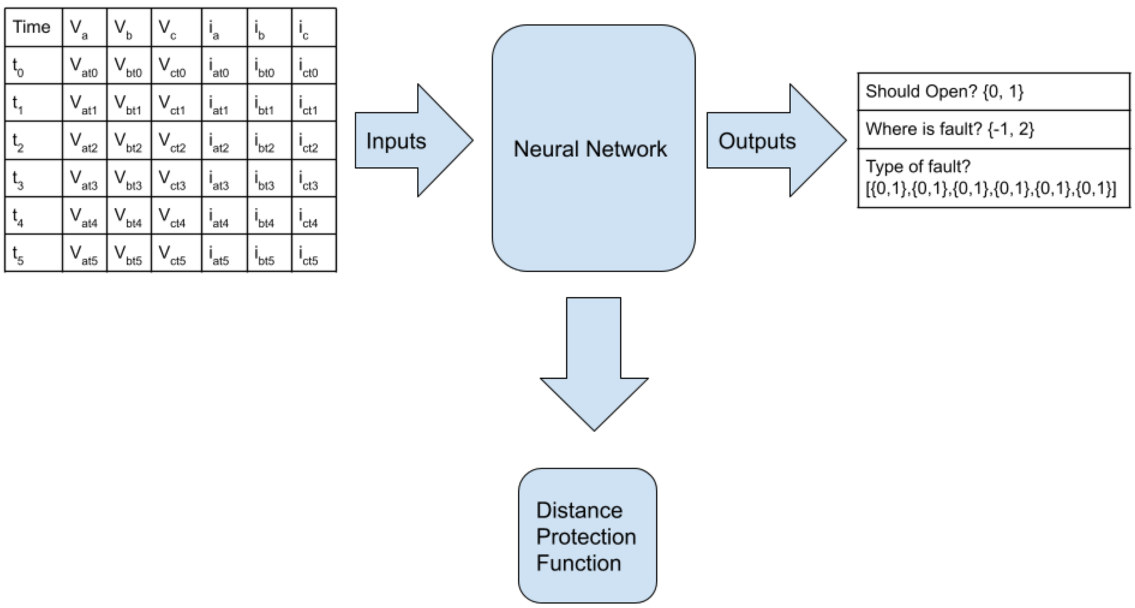
5.8 Results

Our result is going to be an accurate function that allows us to analyze a group of faults that will then determine if a circuit breaker needs to operate. This will ensure compliance with the requirements by being able to accurately detect and categorize a fault that is occurring. If the circuit breaker operates, it helps us to minimize damages to both the environment and the system as a whole.

If everything were to work as planned, we would be able to run many different simulations to collect a bunch of data. From here, Python would analyze the data and be able to craft a function that would accurately determine if a fault was occurring during a certain amount of time. If a fault is detected, our system should send a signal to the circuit breaker. When it receives this command, the circuit breaker should operate and isolate the fault. Our function should then determine the type of fault and the location at which the fault occurred. This would simulate a correct operation of the system and confirm that our design works as expected.

6 Implementation

Figure 3: Neural Network Diagram



As part of our implementation, a large component is the Distance Protection Function that we need to find. To do this, we'll train a Neural Network that will be used to produce this function based on our inputs and outputs. Our inputs are a slice of time in which we record the voltage and current in each of the three phases over that period of time. Our outputs are a boolean option on if the breaker should open, a normalized value on where the fault occurred, and a set of booleans that detail what type of fault is occurring. The Neural Network will be trained to produce a function that will produce the desired outputs given the inputs. After our training is complete and we've found a Distance Protection Function, we implement that into PLECS using their C-Script blocks so we may run Real Time Simulations to test our solution.

7 Professionalism

This discussion is with respect to the paper titled " Contextualizing Professionalism in Capstone Projects Using the IDEALS Professional Responsibility Assessment", *International Journal of Engineering Education* Vol. 28, No. 2, pp. 416–424, 2012

7.1 Areas of Responsibility

Pick one of IEEE, ACM, or SE code of ethics. Add a column to Table 4 from the paper corresponding to the society-specific code of ethics selected above. State how it addresses each of the areas of seven professional responsibilities in the table. Briefly describe each entry added to the table in your own words. How does the IEEE, ACM, or SE code of ethics differ from the NSPE version for each area?

Table 4: Areas of Responsibility

Area of Responsibility	Definition	NSPE Canon	IEEE interpretation	Our Interpretation
Work Competence	Perform work of high quality, integrity, timeliness, and professional competence.	Perform services only in areas of their competence; Avoid deceptive acts.	Maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations.	Only perform work that you are competent and able to do at a high standard.
Financial Responsibility	Deliver products and services of realizable value and at reasonable costs.	Act for each employer or client as faithful agents or trustees.	To reject bribery in all its forms.	Maintain financials which are realistic and reflective of the work being done.
Communication Honesty	Reports work truthfully, without deception, and are understandable to stakeholders.	Issue public statements only in an objective and truthful manner; Avoid deceptive acts.	To be honest and realistic in stating claims or estimates based on available data. Avoid real or perceived conflicts of interests.	Communicate with parties involved about everything which may pertain to them. Don't attempt to deceive or trick those involved.
Health, Safety, Well-Being	Minimize risks to safety, health, and well-being of stakeholders.	Hold paramount the safety, health, and welfare of the public.	To avoid injuring others, property, reputation, or employment by false or malicious action.	Ensure that the work being done will keep everybody and the environment as safe as possible.
Property Ownership	Respect property, ideas, and information of clients and others.	Act for each employer or client as faithful agents or trustees.	To credit properly the contributions of others.	Give credit where credit is due. Don't take credit for work not done by you.
Sustainability	Protect the environment and natural resources locally and globally.		To improve the understanding of technology; its appropriate application, and potential consequences.	Ensure that the environment is protected and that due diligence is done to ensure it's protection. Avoid wasteful/harmful designs.
Social Responsibility	Produce products and services that benefit society and	Conduct themselves honorably, responsibly, ethically,	To treat fairly all persons and to not engage in acts of	Treat everybody as equals and make designs that don't aid

	communities.	and lawfully so as to enhance the honor, reputation, and usefulness of the profession.	discrimination based on race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression.	in discriminatory acts.

Differences between IEEE and NSPE:

- **Work Competence:** Pretty much the same, perform work you are competent to perform and disclose limitations in your abilities to perform a task.
- **Financial Responsibility:** IEEE referred to more integrity in not taking bribes whereas NSPE states you should be faithful and in your work for your clients.
- **Communication Honesty:** ASPC moreso states that you should be objective whereas IEEE says honesty and realism is more important with your communication.
- **Health, Safety, Well-Being:** ASPC states keeping everybody as safe as possible where IEEE says the same but adds in not performing false or malicious action. IEEE seems to allude to taking as many precautions as possible which is similar to what ASPC states.
- **Property Ownership:** ASPC seems to think of this in terms of property made for a client or trustee whereas IEEE moreso talks on Intellectual property and giving credit to contributions made by those other than yourself.
- **Sustainability:** ASPC doesn't mention sustainability at all so they differ completely in that IEEE takes into account the understanding of technology and its consequences that it could have on the world.
- **Social Responsibility:** Both talk about treating everyone fairly and equally no matter their circumstances or who they are as people.

7.2 Project Specific Professional Responsibility Areas

For each of the professional responsibility areas in Table 5, discuss whether it applies in your project's professional context. Why yes or why not? How well is your team performing (High, Medium, Low, N/A) in each of the seven areas of professional responsibility, again in the context of your project. Justify.

Table 5: Project Specific Responsibility Areas

Area of Responsibility	Does it apply to our project's professional context? Why?	How is our team performing?	Justification
Work Competence	Yes, we have to constantly learn about new topics in order to complete this (ie Neural Networks, Python Coding, etc)	Medium	Some members of the team have tried to learn more Python coding and we have begun to review the specifics of Neural Networks.
Financial Responsibility	No, we are coming up	N/A	Since we don't have

	with a proof of concept not an actual product.		any financial responsibility to our project our team hasn't done anything towards it.
Communication Honesty	Yes, because in order for our project to work properly we need to be truthful about what parts of the project work and don't work so if we run into issues we can quickly determine where the problem is and fix it.	High	We have viewed where our model does not fit our project and have been able to modify it to make it work a little better. We have also discussed different issues with the collection of data to better our group of data to perform better later on in the project.
Health, Safety, Well-Being	Yes, because it would shut off the line and make it safer for linemen to find faults and fix them.	Medium	Less time searching for the fault location and type can negate accidents occuring in the time searching for these solutions.
Property Ownership	Yes, since power lines go through towns and cities and by crop fields our project will be able to respect the property of the clients by turning off the power lines faster when a fault occurs which should either reduce or completely eliminate damage to their property.	Medium	The faster we can shut off these power lines, results in a greater chance that a fire(or other types of damage) will not occur
Sustainability	Yes, because our project will allow power companies to turn off power lines faster once a fault is detected which will make it so the faults don't have as much time to catch fire to trees or other things that are in the area and cause more damage.	Medium	The ability to negate the possibility of damage that the faults may cause. The time that it detects a fault, to the time the breaker opens is now that much less time that an issue can occur.

	It also will help reduce the amount of energy loss from the fault which will lower the amount of resources wasted from a fault.		
Social Responsibility	Yes, because the goal of our project is to make fault detection easier for power companies so they can shut off the line faster and be able to fix the issue faster so that the community maintains reliable energy.	Medium	The faster we can recognize and respond to the fault will result in less power loss. Less power loss results in saved money and time with the company and its customers.

7.3 Most Applicable Professional Responsibility Area

We believe that communication honesty is one of the most important for our project and we seem to do that very well so far. Having communication honesty means being able to report work done in an efficient and reliable manner. In this sense, we have been communicating very frequently and been able to describe what is going on in our own sections very effectively. We have also been very open about our confidence in this project and the different topics that we are meant to accomplish. Due to this, we have been able to work on the different parts of this project and efficiently communicate within the team of our findings and new ideas.

8 Closing Material

8.1 Discussion

Our project has been an enlightening experience thus far, and has taught us much about our next steps in it. We were able to successfully create a PLECS model that accurately illustrated the problem at hand (Fig. 4) and were able to successfully pull fault data from it to a file. This fault data includes the waveforms of both voltage and current and shows how they change over time (Fig 5). Our research into neural networks has been quite informative and has allowed us to construct a small neural network that just attempts to show how one would operate (Fig 6). The results of this are very promising for our project and we are excited to see how this will translate to ours.

Thus far, most of our requirements have either been handled or are being addressed(ie. NN implementation). Our focus for the time has been on being able to understand the NN and the multiple aspects that will need to be connected to our project and form it all together.

8.2 Conclusion

Up to this point in the semester, we have been able to firstly use a model given to us by our client to create a similar "dummy" model to to represent the transmission system including the source, transformers, lines, faults, and scopes at various points. These scopes provided us with the waveforms similar to the ones explained in figure 5 within 8.4. This model is then run around 400 times with a program that was created by our team to execute our model hands-free. We will need as much data output as we can obtain to help us achieve a more accurate and dependable for our product. We have then been able to create a simple neural network to use for the time being, to run these waveforms through to determine whether or not a fault has occurred, and to decide to open the breakers.

Our goals moving forward will be to grow and debug our neural network to be as accurate as we can be on determining the type of fault, the distance that it occurred down the line, and on it's decision to open the breakers. After the neural network is completed, we will then be using this to run through a real-time simulator to have an accurate depiction of the time it will take running in a real life scenario. We will then attempt to have this decision be made in around 30 milliseconds, which is quicker than current methods used today.

8.3 References

List technical references and related work / market survey references. Do professional citation style (ex. IEEE).

- C. Maklin, "LSTM recurrent neural network Keras example," *Medium*, 21-Jul-2019. [Online]. Available: https://towardsdatascience.com/machine-learning-recurrent-neural-networks-and-long-short-term-memory-lstm-python-keras-example-86001ceaaebc. [Accessed: 05-Dec-2021].
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- J. Brownlee, "Time series forecasting with the long short-term memory network in python," *Machine Learning Mastery*, 27-Aug-2020. [Online]. Available: https://machinelearningmastery.com/time-series-forecasting-long-short-term-memory-network-python/. [Accessed: 05-Dec-2021].
- J. Chen, "Neural network definition," *Investopedia*, 01-Dec-2021. [Online]. Available: https://www.investopedia.com/terms/n/neuralnetwork.asp. [Accessed: 05-Dec-2021].
- "Machine learning," *Wikipedia*, 26-Nov-2021. [Online]. Available: https://en.wikipedia.org/wiki/Machine_learning. [Accessed: 05-Dec-2021].

8.4 Appendices

Figure 4 : This is an example of the type of PLECS model we are using to generate our waveforms.

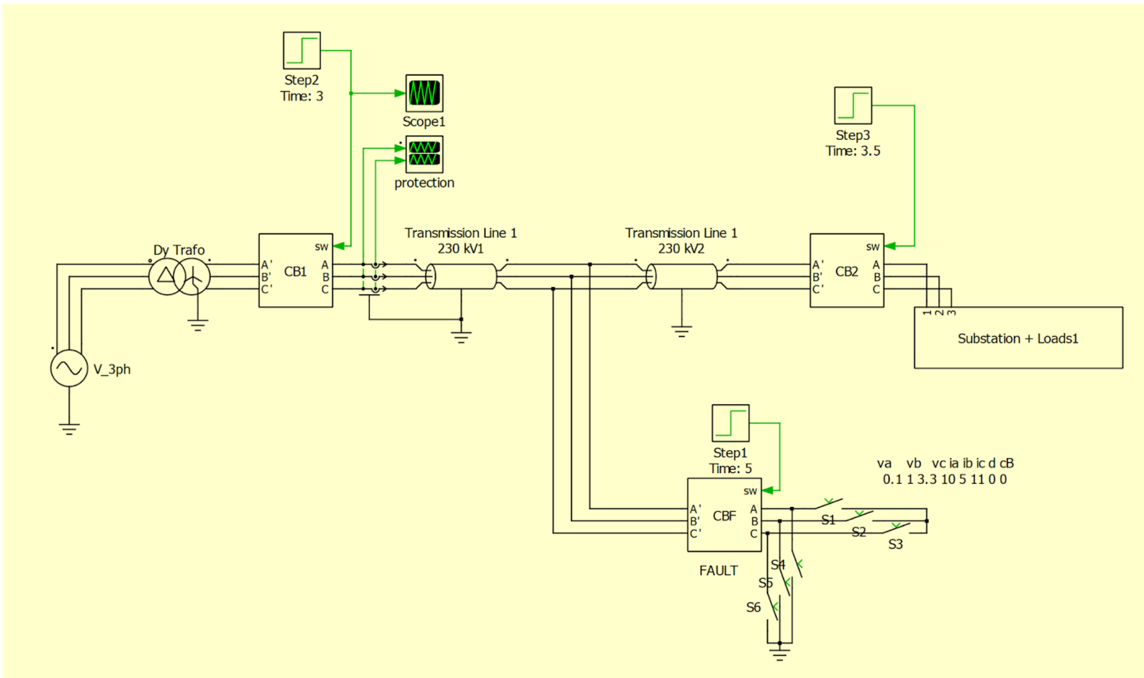


Figure 5: This is an example of ideal waveforms of voltage and current with no fault occurring (left) and a line to ground fault occurring (right).

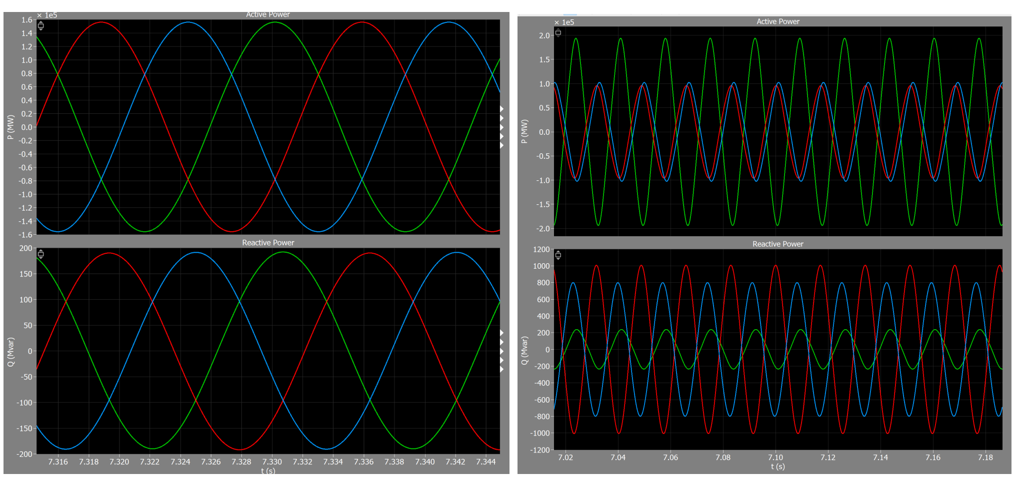
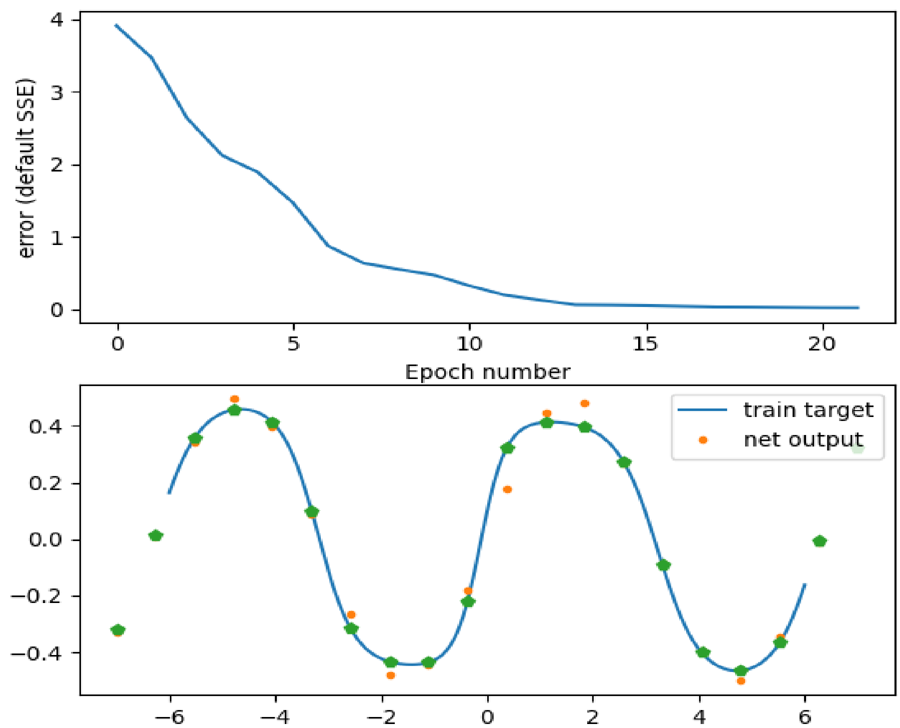


Figure 6: Example of neural network training and results.



Any additional information that would be helpful to the evaluation of your design document.

If you have any large graphs, tables, or similar data that does not directly pertain to the problem but helps support it, include it here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc,. PCB testing issues etc., Software bugs etc.

8.4.1 Team Contract

Team Members:
1) Matthew Dobrzynski 2) Taylor Semple
3) Chye Stecher 4) Anthony Ruffalo
5) Keegan Kraft 6) Josh Vrenick

Team Procedures

1. Day, time, and location (face-to-face or virtual) for regular team meetings: Sundays at 4pm through discord or face-to-face.
2. Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face): Face-to-face communication would be preferred as well as keeping in touch through the discord server.
3. Decision-making policy (e.g., consensus, majority vote): Overall consensus among group members with ties between decisions being discussed with TA or client.
4. Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived): Matthew Dobrzynski will be responsible for keeping meeting minutes while Taylor will be outlining deadlines met and actions to be completed by the next meeting time.

Participation Expectations

1. Expected individual attendance, punctuality, and participation at all team meetings: All team members are expected to attend meetings unless some reason is communicated to the group for being unable to attend the meeting. Discord attendance may also be used when face-to-face is undoable.
2. Expected level of responsibility for fulfilling team assignments, timelines, and deadlines: Everybody is expected to meet their deadlines or communicate issues with meeting a certain deadline and adjusting the timeline when needed.
3. Expected level of communication with other team members: Everyone is expected to be able to communicate over discord and respond to @everyone messages or individual pings within the day.
4. Expected level of commitment to team decisions and tasks: Everybody is expected to devote enough time for scheduled group meetings and tasks that are assigned to the group.

Leadership

1. Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):
   Team Organization: Taylor
   Client Interaction: Matthew
   Individual Component Design: Josh, Chye
   Testing: Keegan
   Software Engineering: Anthony

2. Strategies for supporting and guiding the work of all team members: Communicate responsibilities and work to be done so that all group members are aware of what tasks should be completed by who.

3. Strategies for recognizing the contributions of all team members: Crisp high-fives with words of encouragement.

Collaboration and Inclusion

1. Describe the skills, expertise, and unique perspectives each team member brings to the team. EE's with power emphasis, One EE with VLSI emphasis, One SE with Software understanding and knowledge, Understanding of model evaluation and testing.
2. Strategies for encouraging and supporting contributions and ideas from all team members: Give ideas brought forth by group members a chance and discuss the pros and cons of those ideas. Discuss things in a professional manner that retains the integrity of the group.
3. Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will a team member inform the team that the team environment is obstructing their opportunity or ability to contribute?): Be honest with your thoughts and provide critiques in a professional manner. Don't be hesitant to relay dissatisfaction with the group.

Goal-Setting, Planning, and Execution

1. Team goals for this semester: Simulate a judicious transmission system for distance protection studies in PLECS, Frame mathematically the design constraints for distance protection to define a reward function for reinforcement learning.
2. Strategies for planning and assigning individual and team work: Break up work as decided and in a way that keeps all group members knowledgeable about each component to the project as a whole.
3. Strategies for keeping on task: Meeting deadlines, completing micro-tasks, and attending meetings with the intent to get work done.

Consequences for Not Adhering to Team Contract

1. How will you handle infractions of any of the obligations of this team contract?: Bring up perceived shortcomings to the group member and discuss with the group as a whole. Potentially shifting of responsibilities or tasks to keep the group moving forward as whole.
2. What will your team do if the infractions continue?: Bring up the issues with the TA for guidance to resolve the conflict, should infractions continue work with TA to determine what further actions should be taken.

****

a) I participated in formulating the standards, roles, and procedures as stated in this contract.

b) I understand that I am obligated to abide by these terms and conditions.

c) I understand that if I do not abide by these terms and conditions, I will suffer the

consequences as stated in this contract.

1) ___________Matthew Dobrzynski____________________ DATE ______9/19/2021____________

2) ___________Anthony Ruffalo________________________ DATE ______9/19/2021____________

3) ___________Chye Stecher___________________________ DATE ______9/19/2021____________

4) ____________Taylor Semple____________________________ DATE ______9/19/2021_____________

5) ____________Keegan Kraft_____________________________ DATE ______9/19/2021_____________

6) ____________Joshua Vrenick___________________________ DATE ______9/19/2021_____________