Testing Voltage and Wire Continuity

Design Document

Senior Design Group 13

Chris Williams

Sam Kline

Aaron Eaton

Matt Kelly

Mohamed Almansoori

Sponsor: Grace Engineered Products

Advisor: Nathan Niehart

Version 1.0

October 15, 2017

Table of Contents

List of figures/tables/symbols/definitions

NOTE: This template is a work in progress. When in doubt, please consult the project plan assignment document and associated grading rubric.

1 Introduction

1.1 Acknowledgement

This project was proposed and made possible by Grace Engineered Products.

1.2 Problem and Project Statement

The problem that we are solving is that currently when technicians are going to be working on power lines they need to test to make sure the voltage is off so they don't get electrocuted, so they use a device that measures voltage that is mounted in a substation cabinet. When the device reads zero voltage, because the power line is underground, there is no way to know if the power line is actually at zero voltage or the device has been disconnected from the power line. We need to be able to both read the voltage of a three phase system to make sure the voltage is zero, and be able to test that the device is connected to the power lines to make sure the reading of zero volts is accurate.

To do this we want to make a device that can be mounted in a substation cabinet. The device will be able to measure the voltage of the power lines and give an accurate reading of any voltage between 3V and 600V. The device will be connected to the power lines by wires, to make sure the voltage reading is accurate when it reads 0V the device will be able to test wire continuity. The device will be able to be powered by a battery so it can operate when the power lines are off, it will have 4 display lights. 3 of the lights will indicate whether the voltage is 0 or not for each phase (3 phases) and the 4th light will indicate if the wire continuity test fails, indicating a 0V reading for any phase is inaccurate. If we are able to build this device, it will help technicians have safer working conditions when they are working with power lines.

1.3 operational Environment

We can guarantee that this device will be used in a protected environment. However, it must be able to handle being connected to high voltages.

1.4 Intended Users and uses

This device's intended use it to monitor a three phase voltage system and report both the presence of voltage and any disconnected wires. It will be used by trained technicians who are working with three phase systems.

1.5 Assumptions and Limitations

Our device won't need to make many assumptions about how it is used. The only assumption that exists right now is that all of the test wires for the device be connected while it is in use.

Our devices specifications have been laid out very clearly, so we have a good idea of what its limitations will be. Its maximum voltage is 600V RMS AC at 50-60Hz, which is high enough to measure most three phase systems. Additionally, this device must be small enough to be mounted in a cabinet.

1.6 Expected End Product and Deliverables

Our team's goal for this project is to deliver a reliable device that can be used by Grace Engineered products. The software team is working on developing a device, which can measure the voltage in a 3-phase system (up to 600v). Also, it would be able to detect the presence or absence of voltage (down to 3V minimum). The electrical team is working on wire continuity that determines the wires connected to the test points are not broken.

Ultimately Grace Engineered Products wants to sell a device which matches our prototype. It will not be exactly the same as what we make because we will be using an Arduino while they will print an integrated circuit with a microprocessor which meets their needs. Other arbitrary aspects of the product (cables used, chassis) will likely be different.

Deliverables

- November 2017
  - Circuit Design for measuring voltage in three-phase system
  - Block diagram for checking wire continuity
  - Cabinet Setup
- December 2017
  - Create the conceptual solution for the device
  - The design document
- January 2018
  - Design a prototype device
  - Working on hardware
- March 2018
  - Troubleshooting/testing
- April 2018
  - Completed testing plan
- May/June 2018
  - Testing plan executed

2. Specifications and Analysis

There are two major parts to our project. The first part is measuring voltage which Grace Engineering Products, Inc. wants and is required to be able to detect if the voltage on any of the three phase lines are 3V or higher. Our initial design to measure the voltage was to use a transformer to step-down the voltage to a level an Arduino could be able deal with which is 0 to 5v. Following the transformer is a full wave rectifier to keep the voltage positive. Lastly, a capacitor was placed across the voltmeter to allow the voltage to appear as DC voltage rather than an AC voltage. This design would work well unless a low voltage was given to the primary side of the transformer, and a 1.4 voltage drop would happen after the transformer due to the full wave rectifier. Thus, this design has some useful ideas but does not accomplish the goal of measuring voltage above 3V. Our next idea is to simply use a zener diode to clip the voltage of the input signal to 5V on the positive side and -5V on the negative side. We would then use a full wave rectifier to keep the voltage positive. A capacitor would then be placed across the voltmeter to make the voltage appear more like a DC voltage than an AC voltage.

The second part is to determine if the lines of the three phase system are actually powered down or if the wires are broke. The wires being broken would make the system appear powered down when the lines are actually live. Our first approach was to look at time-domain reflectometry (TDR) which would send a signal down the wire, and a reflected signal would return if a break was present. The impedance could be found by analyzing the amplitude, and the distance of the break could be found by analyzing the time it takes the reflected signal to return. One requirement of TDR is that a high frequency oscilloscope is required which may not be feasible, but TDR would determine exactly where the break in the wire was at. Another possible solution to the wire continuity problem is a switch circuit where we have switches open a way to test individually each line, like line A to line B, if a signal can be measured on the other end. If so, then there is no break in the wire. Unlike TDR, the switch method would not be able to specify where break was exactly, but the requirement is to determine if there is a break in the wires.

2.1 Proposed Design

We plan to use the zener diode circuit to solve our measuring voltage problem because it fulfills the role of being able to measure a minimum voltage of 3V across any line whereas previous ideas have not been able to do so. In terms of a wire continuity solution, the team is looking at either the switch circuit or TDR. Both can indicate if there is a break in a wire which is required. However, TDR could determine where the break is located, but this is not required.

2.2 Design Analysis

The zener diode solution for measuring voltage would work no matter the input voltage as long as the zener diode can handle the input voltage. The zener diode would bring the voltage down to 5V. Then, a full-wave rectifier is used to make the voltage only positive. A capacitor is then placed across the voltmeter to make the AC voltage look similar to a DC voltage. However, the capacitor will cause the voltage to ripple, and this can cause an uncertainty in the voltage reading since DC voltage is constant. Thus, the measured voltage could be the average of the ripple or any value inside the ripple. This uncertainty could be the difference between being below 3V or above 3V depending on how large the ripple is.

The switch circuit would be able to tell when a line has a break in one of the wires, but could not determine where. Also, the switches would need to be programmable to flip them based on which lines are being tested. The switch circuit would need to be done for line 1 to line 2, line 1 to line 3, and line 2 to line 3 to determine which line has the break. If there is a break, 2 of the 3 tests would indicate a break since each line is in 2 of the 3 tests. If two or more lines were broken, then the circuit would not be able to indicate which one, if any, were not broken.

TDR would be able to tell when a line has a break in one of the wires but requires a high frequency oscilloscope to detect the high frequency signal sent down a line. TDR would be able to pinpoint to a given distance where the break would be located.

3 Testing and Implementation

Testing has not occurred yet since we are still in the design phase of our project. Once we have agreed on acceptable designs for reading voltage and determining wire continuity, we will begin testing. We will have to work with our clients to determine what resources they can provide us to aid in the testing process, and what resources we will have to acquire ourselves. Section 3 will be filled out once we have entered the testing phase and made some prototypes.

3.1 Interface Specifications

– Discuss any hardware/software interfacing that you are working on for testing your project

3.2 Hardware and software

– Indicate any hardware and/or software used in the testing phase

– Provide brief, simple introductions for each to explain the usefulness of each

3.3 Process

– Explain how each method indicated in Section 2 was tested

– Flow diagram of the process if applicable (should be for most projects)

3.4 Results

– List and explain any and all results obtained so far during the testing phase

- – Include failures and successes
- – Explain what you learned and how you are planning to change it as you progress with your project
- – If you are including figures, please include captions and cite it in the text

• This part will likely need to be refined in your 492 semester where the majority of the implementation and testing work will take place

4 Closing Material

4.1 Conclusion

Our goals in this project are to read voltage and determine wire continuity of a 3 phase system in a way that is unique from solutions of other companies. So far this semester, our team members have each learned about 3 phase systems and other relevant information so that we all now have a common knowledge base on the subject. We met with our clients and identified several important requirements that would guide our design process. We split into two teams, addressing the voltage reading and wire continuity problems, and each team has proposed several possible solutions to our client over the past several weeks. We have received feedback from our clients and faculty advisor on each of our proposed solutions, and we are still working on refining our designs to fit exactly what our client wants. Each time we propose a solution, we take careful note of any new requirements or restrictions that are identified in order to make our next design better. In the coming weeks, we hope to identify solutions for reading voltage and determining wire continuity that fit our client's needs, then we will work on combining both solutions into one circuit. Our current plan of action is similar to the agile methodology, since we have frequent contact with our clients and present a new product at each meeting. This is the best plan of action because our clients don't have a specific plan for the design of this product, so requirements could change rapidly. Also, our team members don't yet have as much knowledge on the topic as our clients and faculty advisor do, so frequent meetings to receive advice on our designs is a valuable asset to us.

4.2 References

This will likely be different than in project plan, since these will be technical references versus related work / market survey references

"Time-domain reflectonomy." *Wikipedia, The Free Encyclopedia*. Wikipedia, The Free Encyclopedia. 1 Sept. 2017. Web. 20 Sept. 2017. <https://en.wikipedia.org/wiki/Time-domain_reflectometry>

4.3 Appendices

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

If you have any large graphs, tables, or similar that does not directly pertain to the problem but helps support it, include that 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.