

**Final Report: OpenZmeter Data Analytics Integration**



**4/28/2024**

**Written by: Kole Hall, Nate Hawkins, & Tyler Wolfe-Driver**



## Table of Contents

Summary	Pg. 3
Introduction	Pg. 3
Problem Statement	Pg. 3
Background	Pg. 3-4
Description of Design	Pg. 4-5
Ethics & Safety	Pg. 6
Engineering Specs Verification	Pg. 6-8
Codes & Standards	Pg. 9
Manuals/Troubleshooting Guides	Pg. 9
Conclusions & Recommendations	Pg. 10-11
References	Pg. 12
Appendix A	Pg. 15
Appendix B	Pg. 43
Appendix C	Pg. 51

## Summary

The project's original scope was very open-ended, allowing the team to pursue any topic they were interested in. The group viewed this as an opportunity to tackle an issue near and dear to the hearts of many who live in wildfire-prone and impacted regions across the country. The OpenZmeter V3 GPS provides an affordable, open-source platform that already sports many measuring features, such as powerline event detection, which has the potential to classify events on energized lines known to cause wildfires. While the open source platform favors additions to the hardware/software to make this idea possible, there were and still are existing information gaps that were the team's main focus throughout the project after receiving the OpenZmeter V3 GPS. Some of these instructions developed by the team are the only ones of their kind and will be provided to the next group of seniors to prevent them from encountering the same issues.

## Introduction

### ***Problem Statement:***

**Our aim was to enhance one of the OpenZmeter device models with a new feature that would leverage its open-source attribute, thereby adding significant value to the device.**

### ***Background:***

The increasing amount of roadblocks has caused the project scope to shift significantly. The team's scope now is mainly the development of documentation to support new users, protect buyers from the same problems encountered throughout the project, and compare the meter to a similar but more expensive, industry-trusted device. The documentation created by this team consists of an analysis of problems with the meter and suggestions to fix them in categories such as Wi-Fi connectivity and setting up the testing equipment. This will allow future teams that work

with the Open-Z-Meter (OZM) to bypass the roadblocks this team has encountered and allow for an easy setup process to begin their work. This is vital information that was requested by one of the inventors in the ending stages of the project. We will be reviewing all of our work and turning it over to Dr Reising for the next group of seniors to continue to work on, underscoring the immense importance of our project's outcomes.

### Description of Design

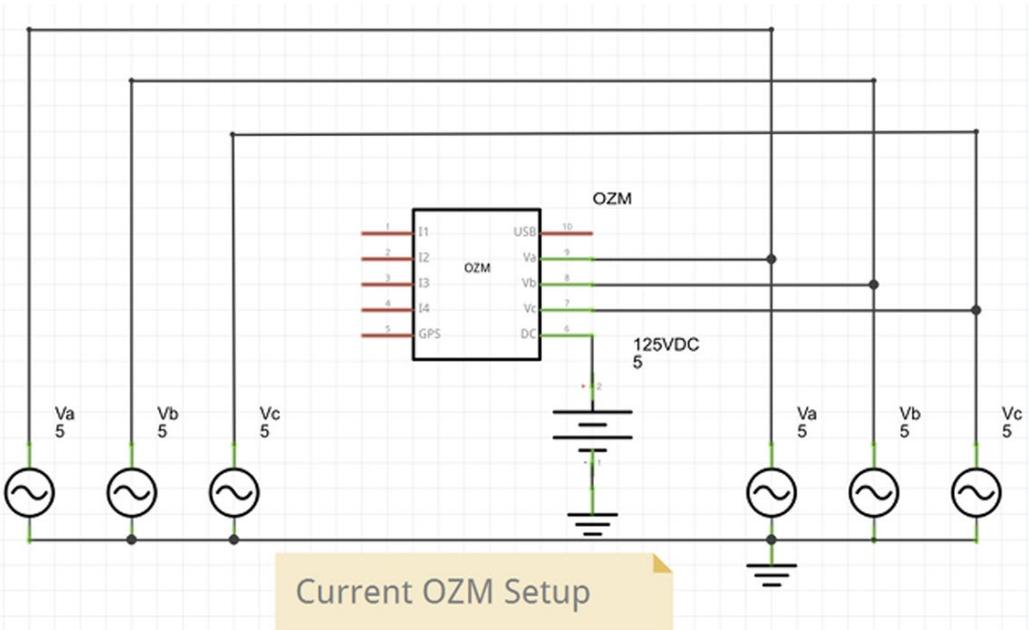


Figure 1: OZM Setup

Figure. 1 provides a diagram of the desired connections for the meter set up of the meter to the power supply, which, in our case, is the Doble simulator. The red wire is  $V_A$ , the yellow wire is  $V_B$ , the blue is  $V_C$ , and the black is  $V_N$ . To simulate data from meters controlled by the Tennessee Valley Authority (TVA), the team will use the power system simulator and Syncrowave. The power system simulator will be used to import the data given, and Syncrowave software will be used to verify waveform outputs generated from Protection Sweep V:5.3.

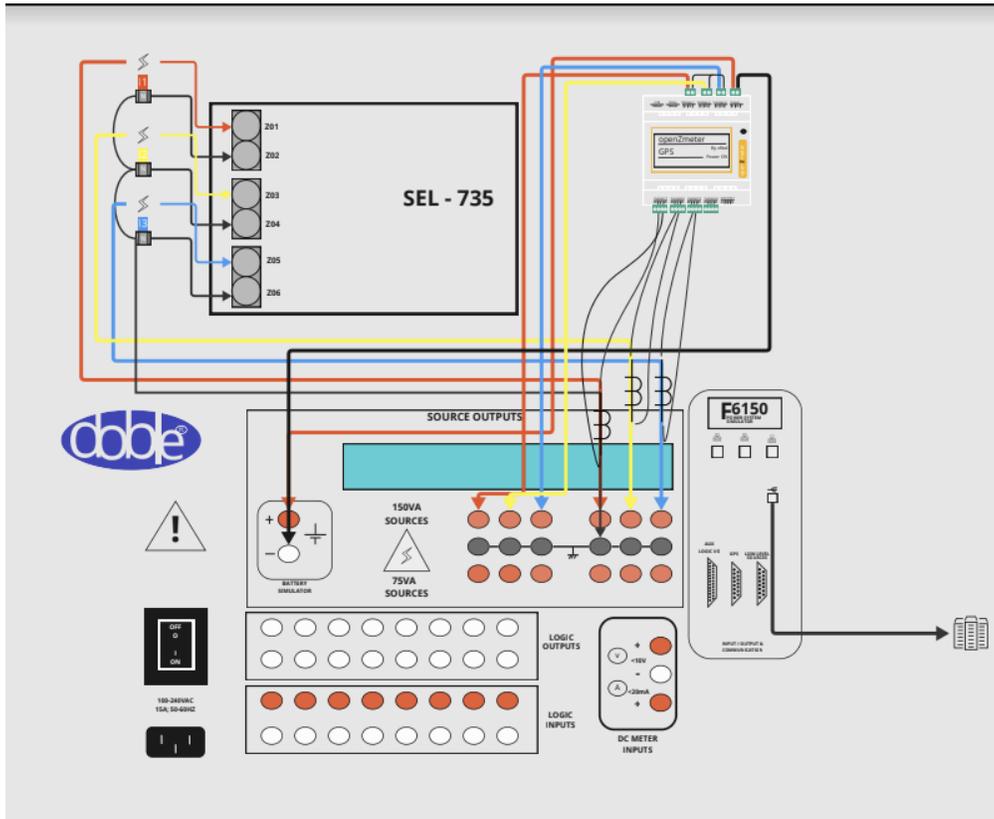


Figure 2: OpenZmeter/SEL-735 wire diagram to the Doble Simulator

Throughout the project, the team decided that having a diagram setup of the equipment connections would be much easier for users to read than just having pictures of the OpenZmeter connections. To create the diagram, we used the micro interface online to draw the images taken of the equipment and color code the connections. This is intended to be a general overview of the equipment setup so that future project teams can see how the three-phase meter and SEL-735 device are connected to the Doble simulator.

## **Ethics & Safety**

### ***Ethics:***

One ethical dilemma that arose while working when mapping out the initial desired functions was the alarm feature. This feature would notify the proper channels if a fault were detected during high probabilities of wildfire occurrence, which was determined from the local weather data and preset parameters. This dilemma was over the proper channels to notify with the presence of an event, and the team eventually settled on a list of the utility and appropriate local authorities. In this instance, the utility could have been chosen to be the sole receiver of this alert, and the rest could have been put in their hands. However, the team felt it was an obligation to include the alerting of proper channels for local authorities and not leave it solely to the utility. This way, time would be saved, and the notification of authorities would be guaranteed by sending the same message with the assumed location of the fire to everyone who needed to be notified in the same alert.

### ***Safety:***

With OZM, the initial project goals were set to solve an issue that has caused massive amounts of destruction and loss. Wildfires are an increasing issue in the world, and with the power industry catching a lot of attention on mitigation practices for these wildfires, the team felt as if it would be a valuable function to implement into the OZM. The project's initial goal was not obtained due to factors that were out of the hands of the team. The project's initial objective was to mitigate the damages to public health and the environment and promote the safety and welfare of the public. This was all to be done on an inexpensive metering device that was open source so that this could become a more and more viable solution with every addition to it. However, the

project's initial scope was changed considerably due to uncontrollable circumstances, and therefore the work done by the team was to assist future users of the OZM through much-needed documentation on the device.

## **Engineering Specs Verification**

### *Specifications:*

- Faults with no significant change in resistivity in-line are likely phase-to-phase faults associated with conductor slap. This will be determined using overcurrent & undervoltage measurements from the OZM. This will be tested by setting up the OZM and testing equipment (Doble injection device & program) in room 406. Our lab director, Akram Saad, explained that we can compare the measurements made by our meter against other measuring equipment in the lab to test accuracy. Then, the files that TVA provided from a recorded phase-to-phase event will be simulated using this equipment, and the results found by the OZM will be compared to those of other equipment.
- High impedance faults occur from vegetation in contact with line-mounted or downed conductors; this will be determined utilizing harmonic analysis combined with the overcurrent & undervoltage measurements. The 3rd and 5th harmonics of ground current will be used in a ratio with the fundamental current,  $I_3/I_1$  and  $I_5/I_1$ . These will be set at thresholds of 10% for the 3rd harmonic and 20% for the 5th. This will be tested utilizing the equipment and software in room 406. Again, the highly resistive recorded fault file from TVA will be run, and then the findings of the OZM will be compared to those of other measuring devices in room 406.
- When conditions favor a wildfire and an event occurs, the system will send a fire alert to a local fire department and utility that owns the line within one minute (GPS determines

what department is “local”). This will be tested by simulating a fire-causing event while the weather conditions favor a fire as measured by the OpenZmeter. This will be timed from the moment the signals are injected from the simulating equipment until the message is received on one of our devices.

- Fault location will be necessary when dispatching first responders to a potential fire’s location on the transmission line. This will be done via our feature on the meter using (or calculating, if not already present) the impedance observed on the line at the time of the event. Then, compare it to the impedance (in ohms-per-mile) to the impedance (also in ohms-per-mile) of the transmission line (which is either known via a calculated transmission line constant from the utility or an estimate based on the conductor material). This measured impedance and location reported by the OZM will then be compared to the real distance to the fault (via TVA’s measurements) with at least 95% accuracy (error of about 250 ft). This will be done by simulating a line event via the IEEE COMTRADE files provided by TVA in room 406.
- Vegetation data will be integrated into the software to assist with fire risk analysis. This data will be put on a scale from 0 to 100 (0 being little-to-no vegetation and 100 being extremely thick vegetation) and determined by the GPS location on the OZM. This will be done by manipulating the GPS location of the OZM and comparing it to the actual values of the vegetation from weather and vegetation maps available online.
- The data gathered will be compared from multiple sources to verify weather conditions and vegetation in a specific area, these numbers should be no more than 5% different from one another to be considered successful results.

- Only faults that have validity in being a potential fire will trigger the alarm. Faults using the data given by TVA will be simulated using the testing equipment in room 406. Using this data with varying weather conditions will be given to the OZM to verify that it will only dispatch first responders when both a line event and weather conditions favor a wildfire.
- Reliably tracking weather patterns is an important function of our project. While there are many available sources for local weather information, the most important is testing observed conditions before historic wildfires to make sure our tool is triggering from actual problematic weather and not false reporting to authorities. The way to test this is by feeding temperature, wind, and precipitation quantities to the weather monitoring tool from previous wildfires and ensuring the tool triggers, sending conservative alerts to the utility and area fire departments. If no conservative alert is given from actual historical weather quantities, then the tool isn't accurate. The communication medium for this test will most likely be the "alarm" feature already present in the OHM's software.
- Another important deliverable for this project is to develop literature for the OpenZmeter so that future work with the device can occur with far fewer issues than our team has dealt with. In the words of the OpenZmeter inventor, they have not been able to develop installation guides and operational guides for the device. This group will build installation, simulation, and operation materials to close this information gap for future research.
- Modifications made to the current OpenZmeter software will be available as a downloadable file to the device's inventors and others who would like to add the feature to the OZMV3 GPS and newer models.

All of the above specifications were not met except for developing and testing documentation that will assist future groups. This was due to the lack of documentation provided by the OZM. Therefore, the team focused on creating and presenting the missing documentation so that future users could efficiently and quickly set up the meter and gain access to utilize it in whatever way they saw fit. To top this off, the OZM device the team obtained had firmware issues and was not caught and fixed by the device's inventors until the course ended. This limited the team from developing an installation and setup guide that walks through the initial setup and Wi-Fi wizard, along with the potential roadblocks one might come across. Along with a setup guide that the team developed to utilize once access was gained to the OZM and the above specifications had been implemented.

The steps that need to be taken by future teams are to read over the documentation that the team created and the references that the team had planned on using to implement the functions of the OZM. Next, future teams must access the OZM and familiarize themselves with the interface and the device's functionality. Once these steps are completed, the code will need to be accessed, and the handles of the code that trigger analysis and computation need to be obtained. Afterward, the weather database needs to be created using the information gathered by the team. Once this is done, the future team needs to determine parameters they deem fit to obtain the project's objective. Once this is done, the pseudocode developed needs to be followed to create the code. Once the code is developed, it needs to be implemented on the OZM, and a series of tests need to be performed with the COMTRADE files obtained from TVA. During these tests, the location and each weather data input need to be manipulated to guarantee that the meter functions as desired. From these tests, the future team should be able to determine if the specifications are met and if

the code functions properly. If not, they should be able to troubleshoot and tweak different preset parameters to obtain the desired functionality.

## **Codes & Standards**

**738-1993 - IEEE Standard for Calculating the Current:** This is a standard that the group believes will be useful for further project development. The standard discusses accurate predictions, system reliability, optimal design, dynamic loading capabilities, safety considerations, and economic efficiency. All are important topics when configuring a meter into a system. The group didn't get to that point of the project due to constraints with documentation and time.

**Tutorial on High Impedance Fault Detection:** The following was considered a valuable standard for the metering project as it discusses the importance of environmental considerations, tailored solutions to High Impedance Faults (HIFs), and innovation in protection schemes. Overall, this standard specializes in methods of detection within metering systems to enhance safety protocols.

## **Manuals & Troubleshooting Guides**

This project's deliverable was to develop instructions for moving from a "boxed up" OpenZmeter to a fully powered circuit that is ready to simulate. The guide is available as Appendix A at the end of this document.

During the project, it was difficult to connect the meter to the UTC Wi-Fi, which is essential since the meter is an IOT (Internet-Of-Things) device whose measurements can be observed by devices connected to the same network (after user credentials are entered, of course). The network set-up instructions document can be found in Appendix B.

Lastly, the inventors diagnosed our meter needing a firmware update to meet the latest requirements. Another firmware update may be improbable, but if the situation arises, we have compiled a list of instructions that collaborates with pre-existing instructions provided by the OpenZmeter inventors. Those instructions can be found in Appendix C. We have a video for the system setup, which can be found [here](#).

## **Conclusions & Recommendations**

While the concluding stages of the project were indeed not what the team imagined back in Fall 2023, the issues worked through in collaboration with the OpenZmeter Inventors, professors, campus IT, and even EPRI paved the way for future senior design students to begin immediate work on the functions of the device rather than dealing with connectivity, outdated firmware, lack of instructions for setting up and testing. Additionally, the affirming feedback from industry professionals on possibly preventing wildfires using an IOT-type device such as the OpenZmeter can even serve as a project for the next class, for which this team has already done much research.

There are still some ongoing questions the team has about the meter that haven't been wholly answered:

- What is the extent of accessibility issues with the meter? The team has attempted to solve some of these in the “setting up” process, but what other issues will arise when unrestricted access is granted to a user?
- Is the meter reliable enough compared to more standardized devices to be implemented on a larger scale, such as the TVA system? The team aspired to make one comparison to a more widely used device but could not complete the study before the semester ended.

- What changes can we expect from developers? Will there be more firmware upgrades in the future? Will a new device model be released? The team spent most of the time trying to set up the current model, but these questions weren't asked at the time.
- A broader concern is cybersecurity. This being an IOT device, there was expressed concern at the technology symposium over the layers of security preventing hackers from hijacking the connection, sending false alarms, gaining access to sensitive information, etc. This must be addressed before a large-scale implementation can be made.

## References

- IEEE Approved Draft Recommended Practice for Fault Diagnosis and Protection in Smart Distribution System
- IEEE Power Systems Relaying Committee for High Impedance Fault Detection Technology
- Tennessee Valley Authority (TVA) Real Power Quality Data
- Fault Types by the North American Electric Reliability Corporation (NERC) [tads \(nerc.com\)](http://www.nerc.com)
- “How Do Power Lines Cause Wildfires?” Texas Wildfire Mitigation Project, 9 July 2014, [wildfiremitigation.tees.tamus.edu/faqs/how-power-lines-causewildfires#:~:text=Power%20lines%20can%20ignite%20wildfires,limit%20damage%20to%20the%20system](http://wildfiremitigation.tees.tamus.edu/faqs/how-power-lines-causewildfires#:~:text=Power%20lines%20can%20ignite%20wildfires,limit%20damage%20to%20the%20system)
- Routray, Somesh. “Weather Data Collection: Web Scraping Using Python.” Medium, Towards Data Science, 8 May 2020, [towardsdatascience.com/weather-data-collectionweb-scraping-using-python-a4189e7a2ee6](https://towardsdatascience.com/weather-data-collectionweb-scraping-using-python-a4189e7a2ee6).

- Zuo, Jinhua, et al. “Transmission Line Sag Measurement and Simulation Research Based on Non-Contact Electric Field Sensing.” *Sensors* (Basel, Switzerland), U.S. National Library of Medicine, 1 Nov. 2022, [www.ncbi.nlm.nih.gov/pmc/articles/PMC9655084/](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC9655084/).
- Spencer Kimball. “Hawaii Wildfires Caused up to \$6 Billion in Economic Losses, Moody’s Estimates.” *CNBC*, CNBC, 22 Aug. 2023, [www.cnbc.com/2023/08/22/moodys-hawaiiwildfires-caused-up-to-6-billion-in-economic-losses.html](http://www.cnbc.com/2023/08/22/moodys-hawaiiwildfires-caused-up-to-6-billion-in-economic-losses.html)
- “Global Site Search.” Search, [www.asee.org/search?search\\_filters=%7B%22ASEE.ORG%22%3A1%2C%22Peer+%28Paper+Repository%29%22%3A1%7D&search=Transmission+Line+Sag](http://www.asee.org/search?search_filters=%7B%22ASEE.ORG%22%3A1%2C%22Peer+%28Paper+Repository%29%22%3A1%7D&search=Transmission+Line+Sag). Accessed 15 Nov. 2023
- 738-1993 - IEEE Standard for Calculating the Current ... - IEEE Xplore, [ieeexplore.ieee.org/document/347648](http://ieeexplore.ieee.org/document/347648). Accessed 16 Nov. 2023.

## Appendix A

# Testing the OpenZmeter (OZM) V3 GPS using the Doble F6150 Power System Simulator



**Date Issued: 2/20/2024.**

**Written by: Kole Hall, Nate Hawkins, & Tyler  
Wolfe-Driver**



# Contents:

- [Equipment List..... 3](#)
- [Installing and configuring 3-phase V3 GPS OZM..... 4](#)
  - [Contents & Mounting..... 4](#)
  - [Configuration & Device Information ..... 6](#)
- [Setting up Doble F6150 power systems simulator..... 6](#)
  - [Physical Setup ..... 6](#)
  - [Software Setup ..... 6](#)
- [Simulation..... 6](#)

# Equipment List

The following is a comprehensive list of equipment and devices needed to complete the simulation from start to finish.

- 3-Phase OpenZmeter V3 GPS (OZM)
- Doble F6150 Power System Simulator
- Desktop (Windows is the operating system used in this example)
- A MAC laptop or desktop (for connecting to and configuring the OpenZmeter)
- USB-A to USB-B Cable
- Terminal block to complete a circuit for the OpenZmeter to monitor (SEL-735 Revenue Meter is used in this example)
- Three Current Transducers (Accu-CT ACTL-0750 Series in this example)
- Six terminal-to-probe adapters



Side View



Bottom View (Probe-Side)

- Eight solid wire-to-probe adapters

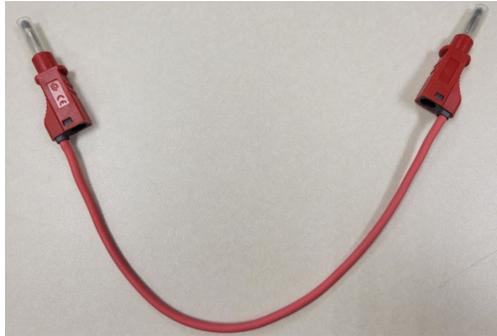


Side View



Bottom View (Probe-Side)

- Six probes of various lengths to connect the devices together in the circuit diagram



Example of probes used in the simulation.

- Two flathead screwdrivers sizes: 1.5mm (for the current input terminals on the bottom of the meter & 2.0mm (for the terminals on the top of the meter).

## Installing the 3-phase V3 GPS OZM

This section will contain information on mounting the OpenZmeter to a DIN rail as well as the standard contents of the packaging, including an order for the 3-phase OpenZmeter V3 GPS.

### Contents & Mounting

When receiving the OZM, the package currently does not include any information to assist in installing or configuring the device.

Two separate are available for purchase:

- The first option does not include current transducers/transformers (CTs) for noninvasive current measurements.
- The second will include them for a higher cost.

Note that currents should never be injected directly into the OZM; they should only be done via CTs. If purchased without the current transducers, the box contains the OZM, two small flat-head screwdrivers for connecting wires to the input terminals, and the GPS monitor. If the second option is selected, the box will include three CTs in addition to the previously listed items. For this simulation, the CTs were purchased separately from the OZM.

When choosing a location to complete the simulation using the Doble power simulator, keep in mind the length of the wires available to create a circuit between the OZM and the Doble and a circuit between a terminal and the Doble for the CTs to measure from.

The OZM can be mounted to any 1 ¾ inch DIN rail. Mounting the OZM is simple. The OZM can be secured to the DIN rail using the white plastic tab on the bottom part of the OZM.

In the image below, the OZM's plastic tab is "slid up," securing it in place. If the meter needs to be moved, simply pull down on the white tab and move the meter to a different location along the DIN rail.



Figure 1 - The OZM V3 GPS mounted to 1.75" DIN rail

## Configuration & Device Information

Configuring the OpenZmeter for the first time is a task containing many steps and has its own set of instructions “[Setting Up the OpenZmeter V3 GPS](#)”. **The simulation cannot be done without configuring the OpenZmeter first.**

## Setting up Doble F6150 power systems simulator

### Physical Setup

**Keep the Doble simulator powered off until instructed while following this guide.**

First, plug the female end of the power cable into the Doble simulator into the port labeled “100-240VAC 15A; 50-60Hz” and plug the male end into an outlet. This is robust equipment, so avoid plugging it into a power strip or junction that is not a receptacle in the wall.

For the connection to your desktop, plug the USB-A end of the USB cable into any available USB-A port on your computer (the one behind the station), and plug the USB-B end into the port on the Doble labeled with the USB symbol shown below:

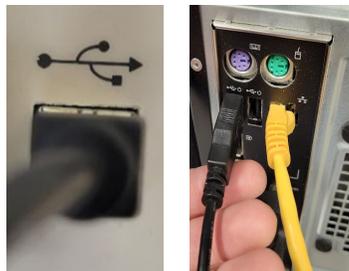


Figure 2 - The left is the port on the Doble for the USB connection to the computer (on the right) containing the simulation software.

The circuit needed to test the OpenZmeter is shown below in its entirety. A comprehensive set of instructions is provided below the diagram, which should be used to make sure the circuit is wired correctly for this experiment.

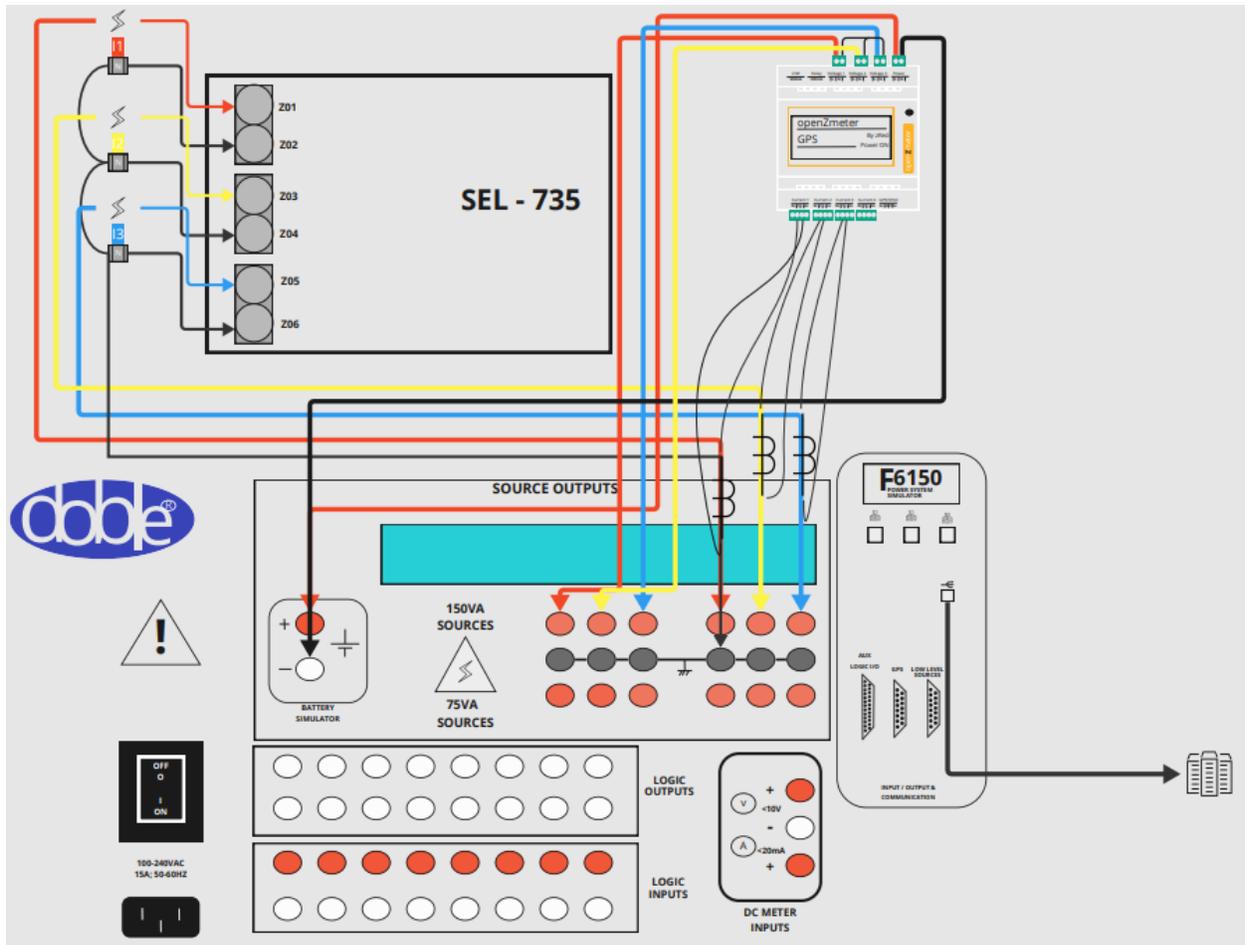


Figure 3 - The completed circuit diagram for the experiment for reference.

### Example of How to Wire OZM Terminals:

- Since each terminal can be removed from the meter, it is a **best practice to add wires to the blocks before reattaching them to the meter**, as shown in the steps below:

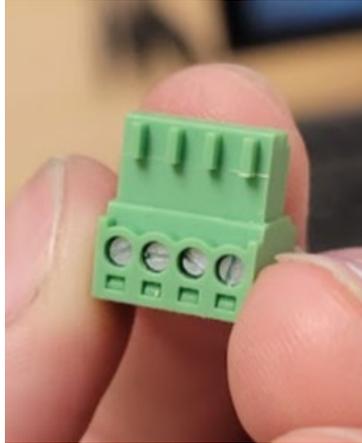


Figure 4 - An example of one of the terminal blocks that has been removed from the meter.

- Loosen the screws as much as possible. When they have been loosened enough, the silver “catches” (circled below) should be at the bottom of the block.

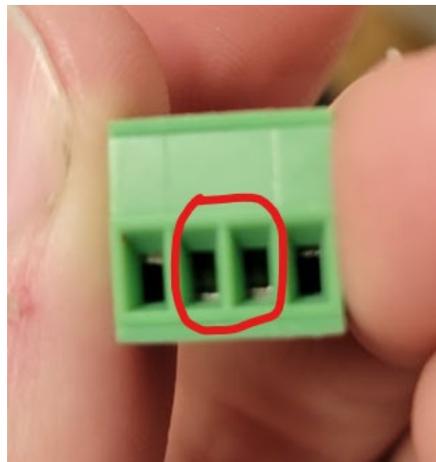


Figure 5 - The terminal block with the fasteners loosened for wiring.

- The next step is to simply add the wires and tighten the fasteners until they catch and hold the wires in place.
- If stranded wires are used, be sure that all strands are twisted together, and that no strands touch from two different wires.

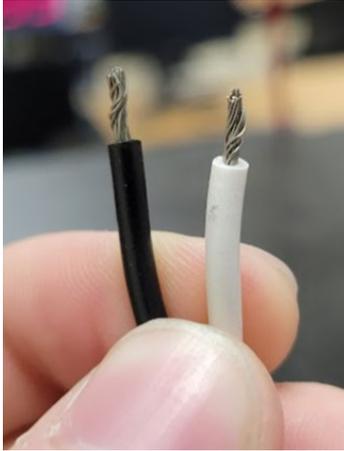


Figure 6 - Properly-twisted stranded wires for the circuit.



Figure 7 - No strands are touching strands from the other wire, and they are secured to the terminal block.

- Lastly, the terminal block can now be placed back in its original location. For this example, it was for “Current 1” on the meter:

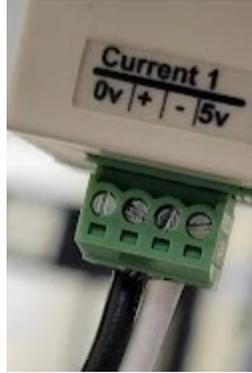
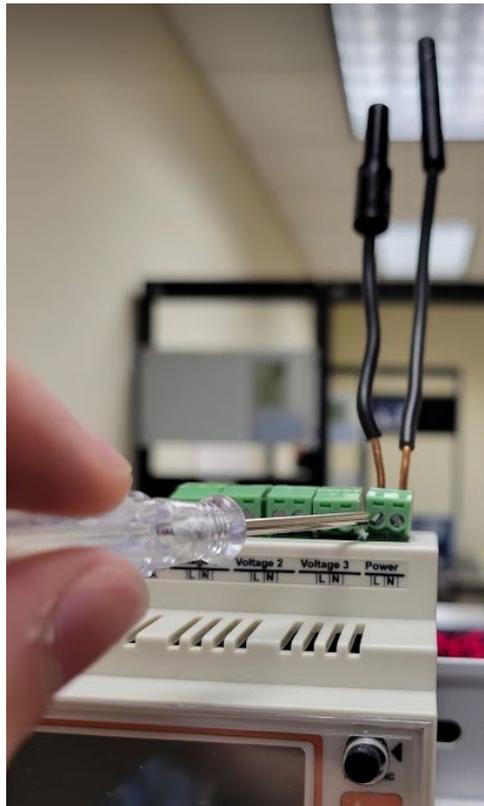


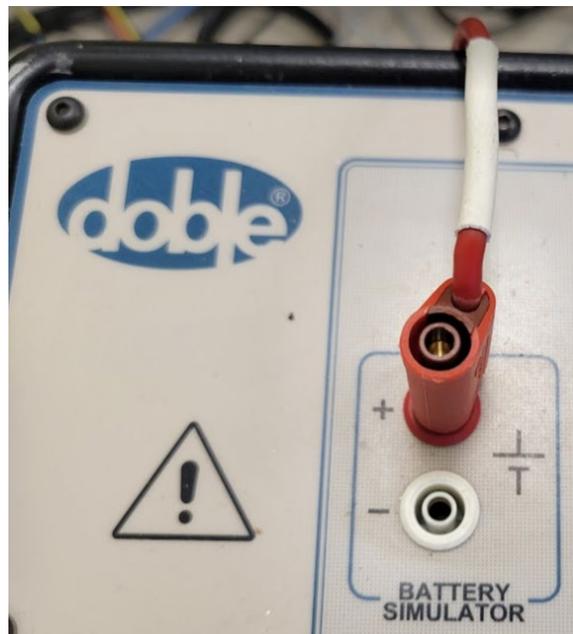
Figure 8 - The wired terminal block has been inserted back into the original location on the meter.

### **Battery Simulator to the OZM**

- To start, secure the wire-probe adapters to the “L” & “N” terminals on the “Power” block of the OpenZmeter.



- Next, plug a red cable into the “+” terminal of the battery simulator on the Doble.

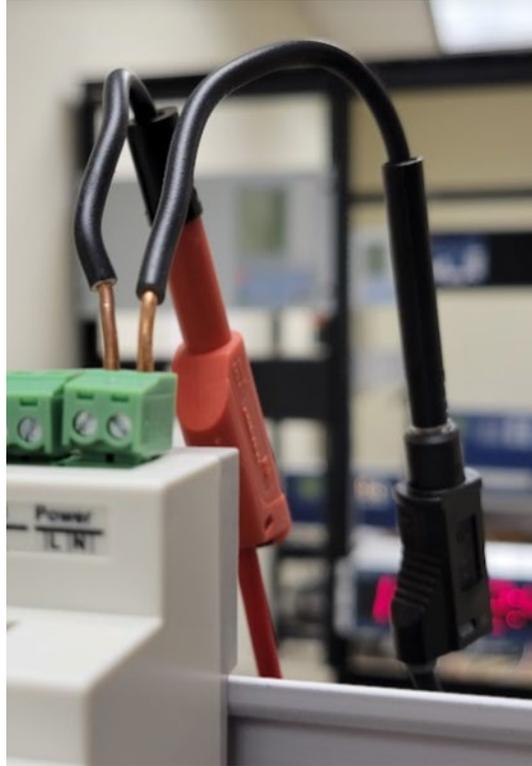


- Now, connect the other end of the wire to the “L” terminal of the OpenZmeter.



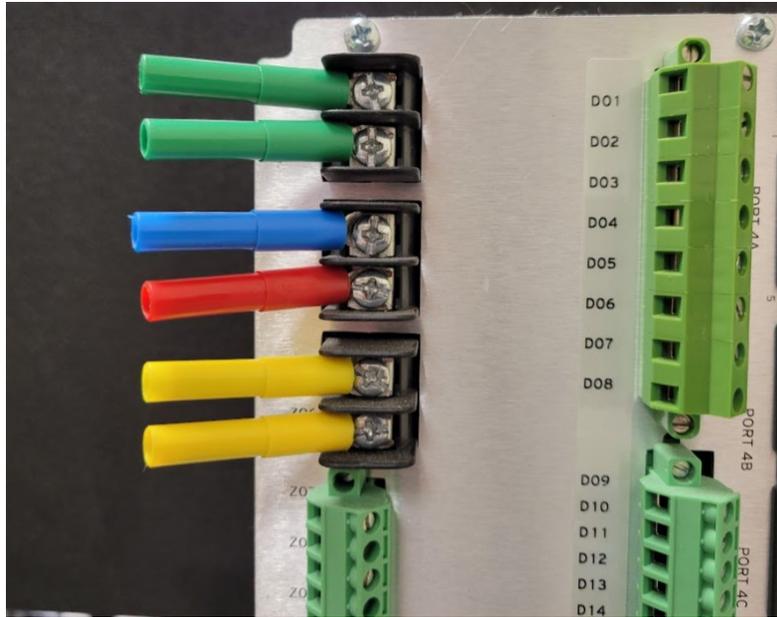
- The “-” terminal on the Doble needs to be connected to the “N” terminal on the OpenZmeter using a black wire, as shown in the two images below:



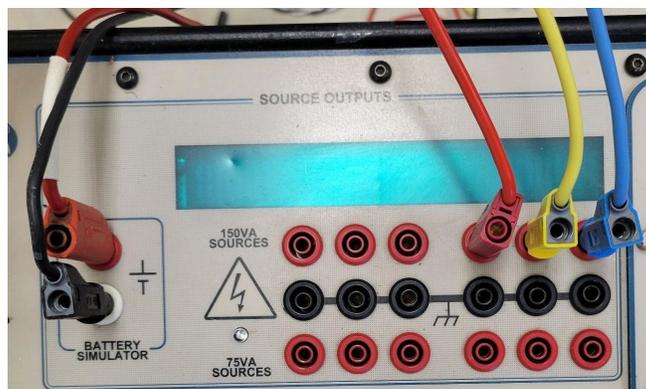


**Wiring the current path for the OpenZmeter to observe:**

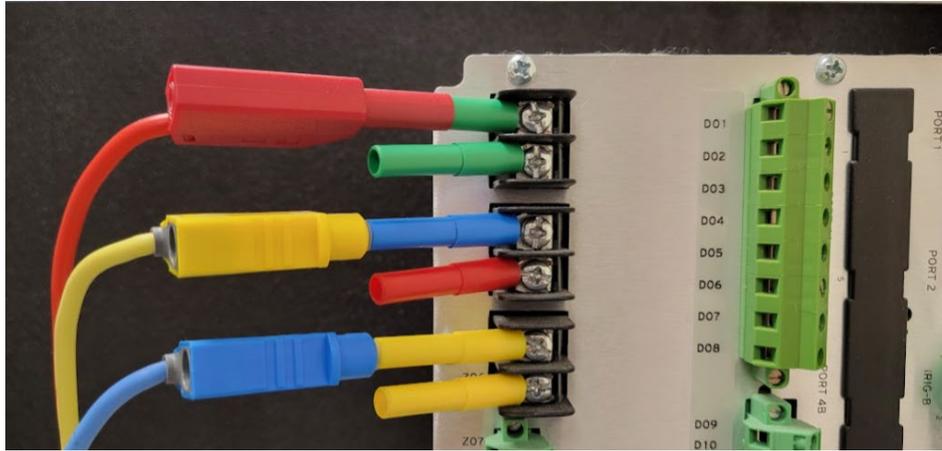
- The back of the SEL-735 Revenue Meter (which is mounted to the left of the OpenZmeter) needs to have the crimped-probe adapters connected to the six top-left terminals as shown below (the colors do not have to match for this step).



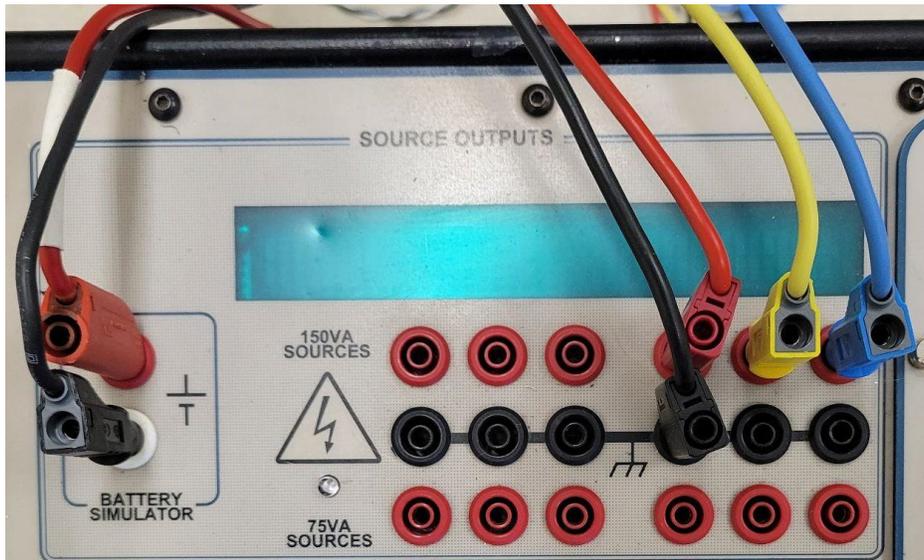
- Now, plug in a red, yellow, and blue wire into the Doble in the manner shown below. In this example, red will be the A-phase, yellow will be the B-phase, and blue will be the C-phase.



- On the back of the SEL-735 Revenue Meter, plug in the other end of the red, yellow, and blue wires as shown below.



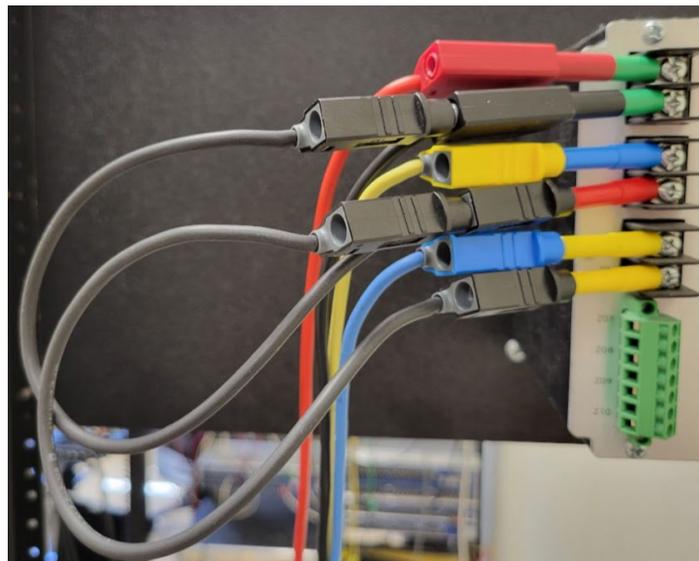
- The next step for wiring the Doble to the SEL-735 is to connect the neutral path. Start by plugging a long black wire into the Doble's neutral terminal, as shown.



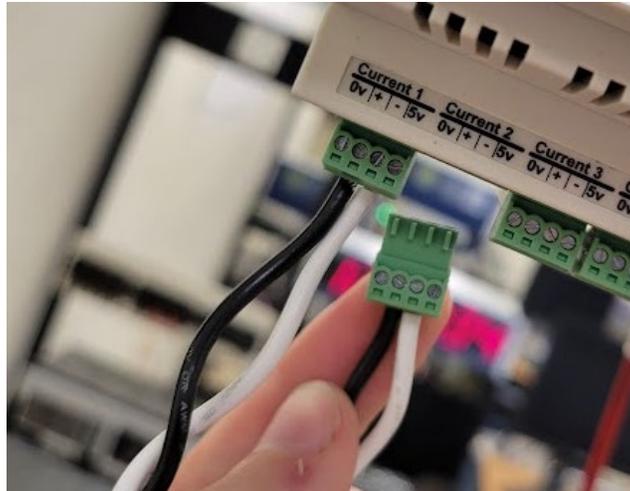
- Plug the other end of the black wire into one of the neutral terminals on the back of the SEL-735:



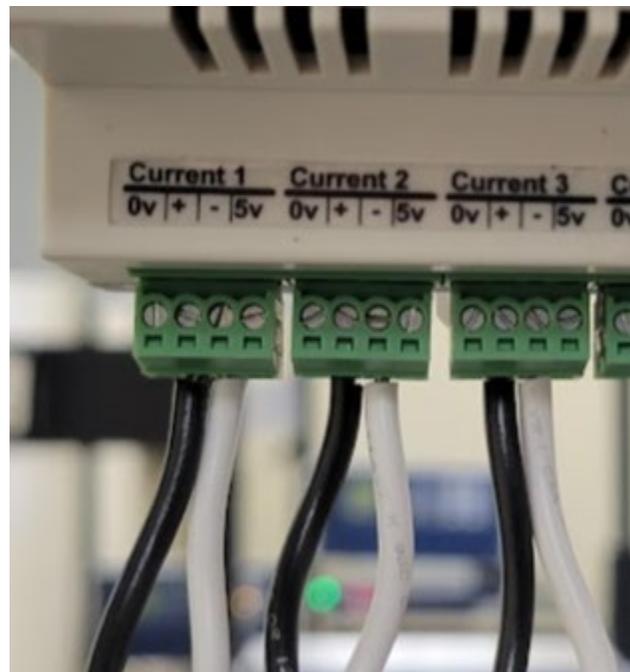
- Since we are creating a Y-Y three-phase connection, the neutral terminals need to be “jumpered” together, as shown in the picture below. Use the short black cables for this.



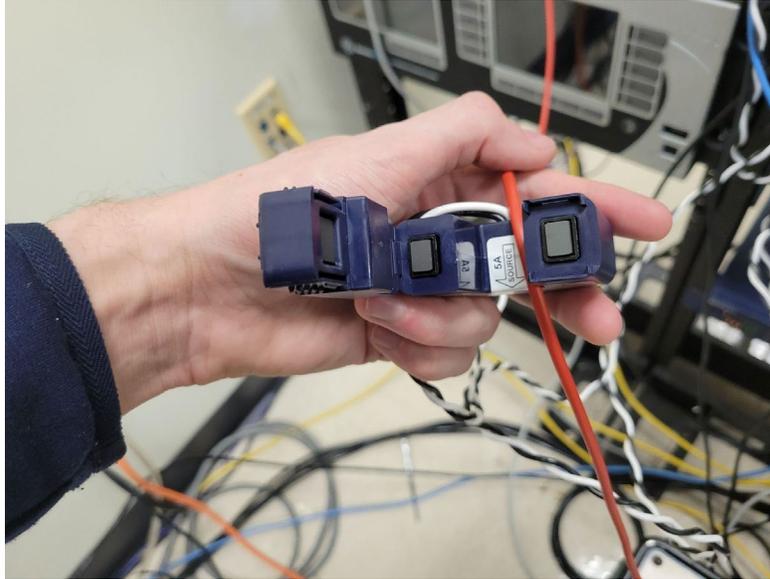
- For wiring, the CT leads to a terminal block on the OZM. See “**Example of How to Wire OZM Terminals**” above. The instructions below begin with “Current 2” and show how the CTs are added to the “metered” circuit.
- Only use the “+” & “-” terminals on the current ports on the OpenZmeter.



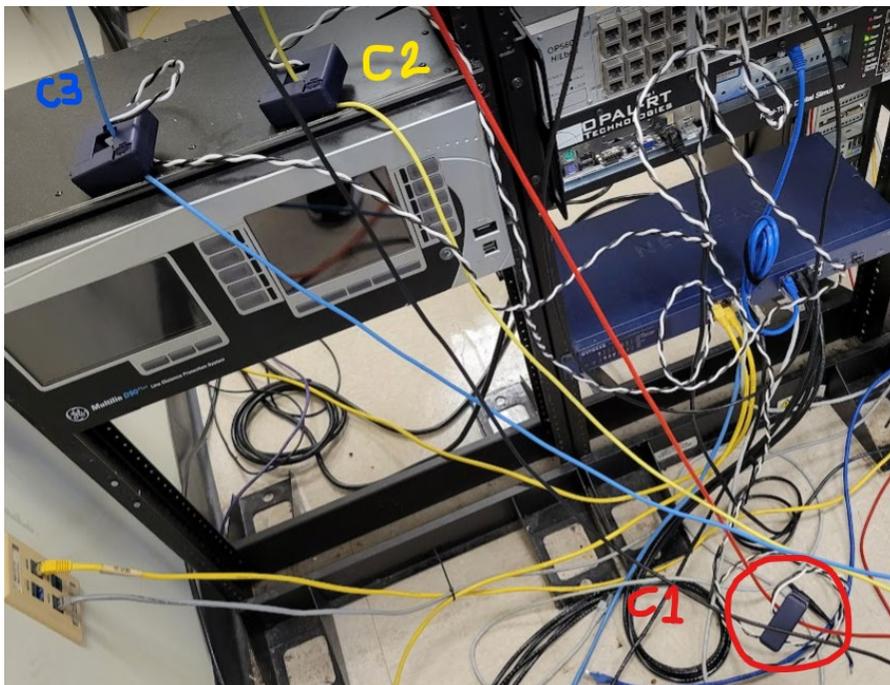
- The below image shows how the current 1-3 terminals on the OpenZmeter should be connected.



- Below is an example of how a CT “clamps” onto a wire:



- Please create separation between CTs when adding them to the circuit to prevent electromagnetic interference during the simulation. An example of how this should be done is provided:



- Make sure the current transducers have the “source” arrow pointed back at the Doble as shown:



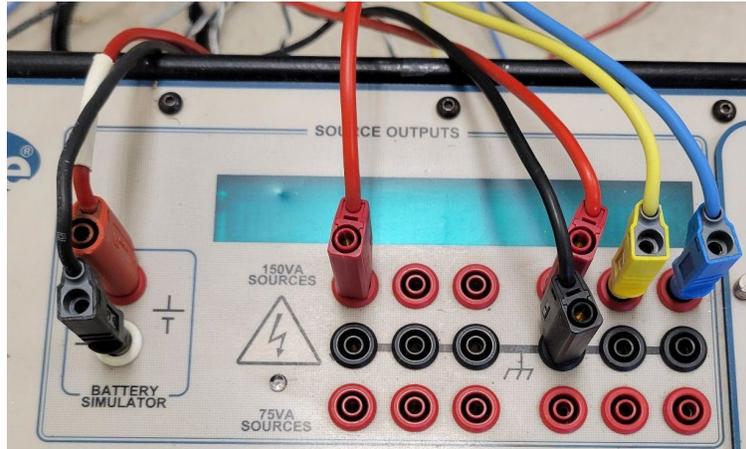
- The CTs should be clamped onto each phase wire (**C1->red C2->yellow C3->blue**).

### **Voltage Connections from the Doble to the OZM:**

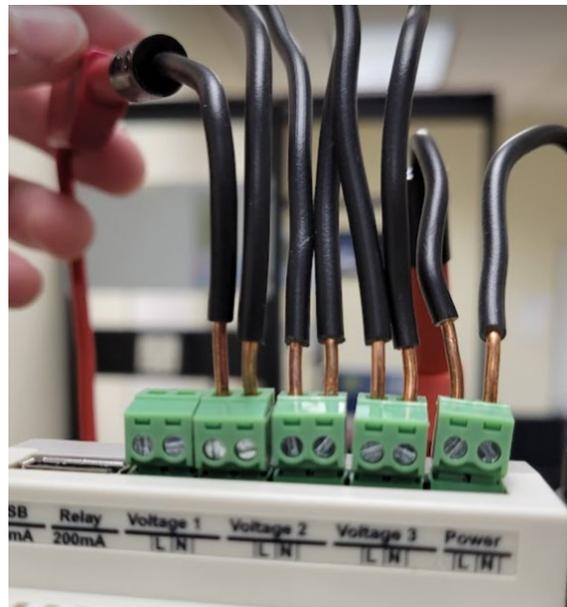
- Connect six more wire-probe adapters to the top of the OpenZmeter in the terminal blocks shown in the image below.



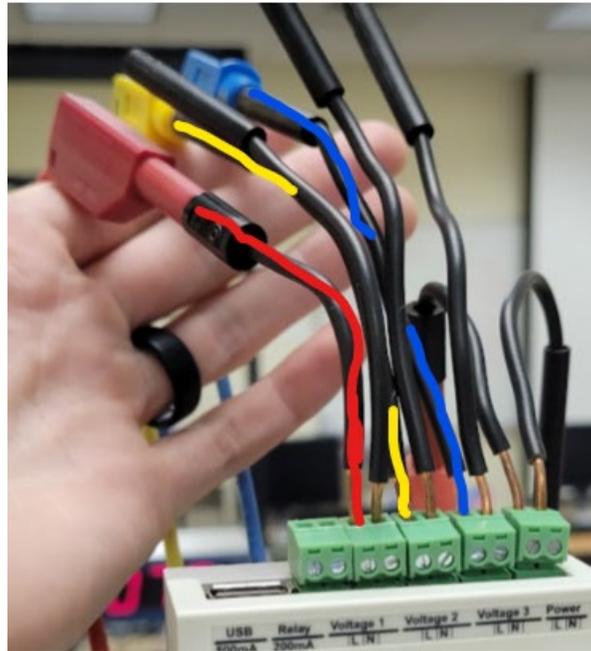
- Plug in another long red wire into the Doble, this time on the terminal shown below:



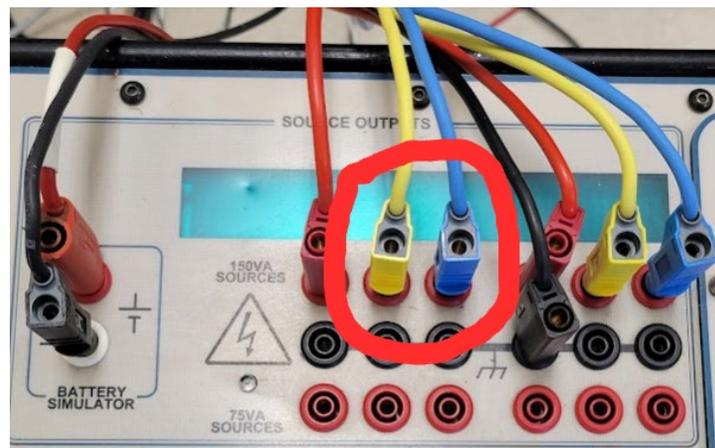
- Plug the other end of the wire into the adapter connected to “L” on the “Voltage 1” terminal block on the OpenZmeter.



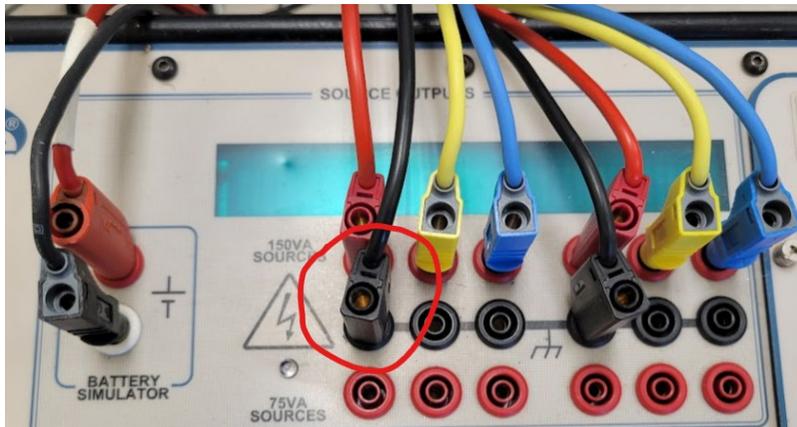
- In the next photo, plug a yellow wire into the “L” on the “Voltage 2” terminal block and a blue wire into the “L” on the “Voltage 3” terminal of the OpenZmeter.



- Plug the other ends of the yellow and blue wire into the Doble next to the red wire. Their location is circled in the image below.



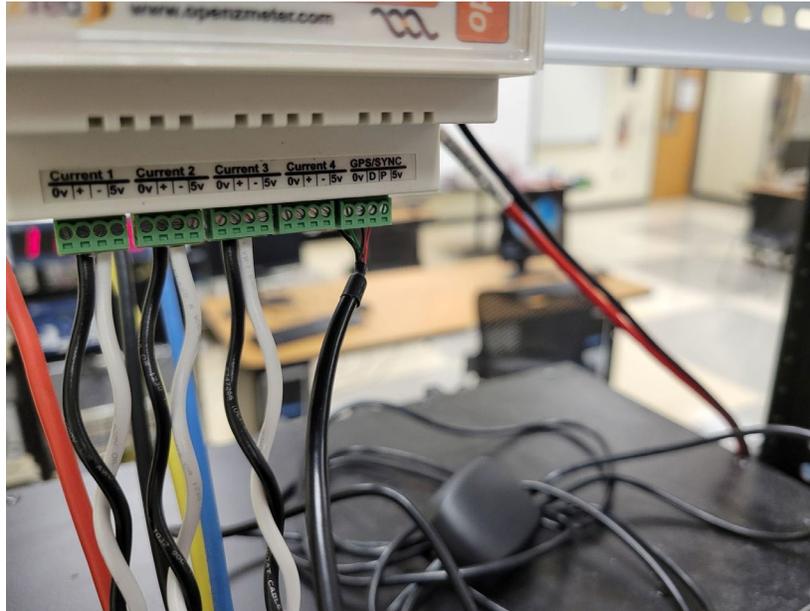
- Now, plug another long black wire into the Doble for the voltage-metered circuits Y-Y connection.



- For the remaining three wire-to-probe adapters connected to the OpenZmeter, connect them using the short black jumpers. Then, plug the long black wire into the back of any one of the now-tied-together jumpers.



- Lastly, plug the GPS module into the bottom right of the OpenZmeter:

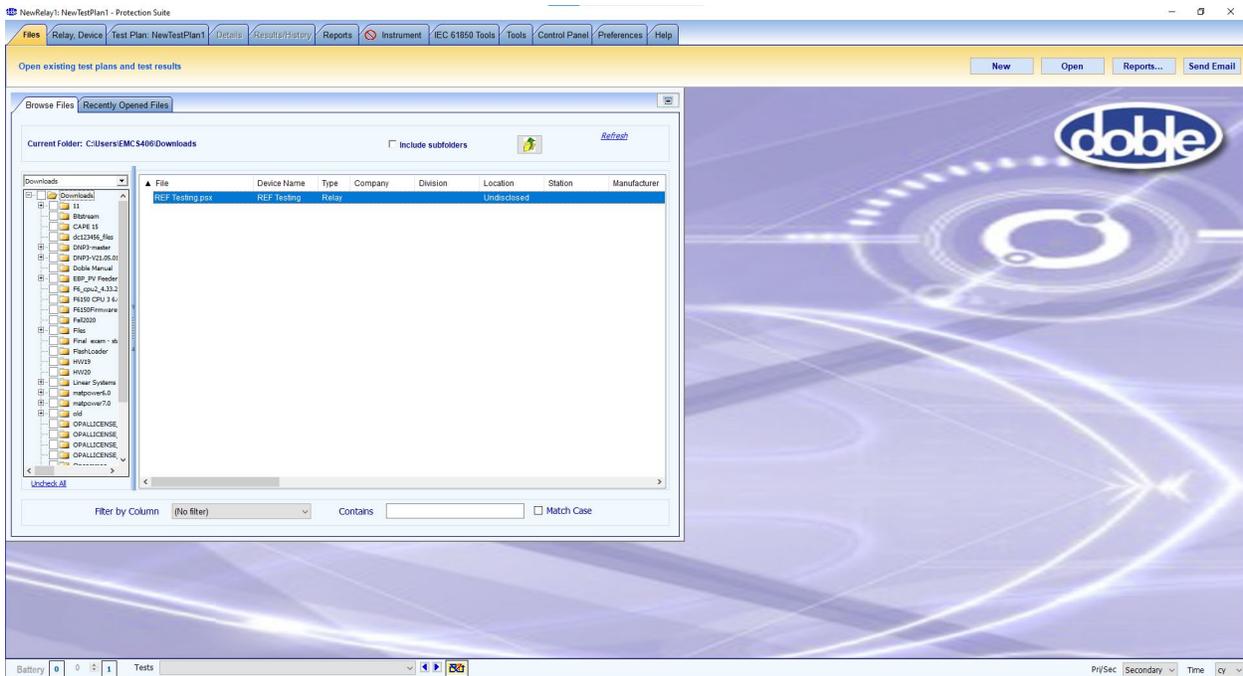


- This concludes the metered circuit connections; please stop here to double-check connections and have a peer check the circuit before proceeding.

# Software Setup

If the Protection Suite software has not yet been installed, please go to [this link](#). A license will need to be purchased/verified for it to work (It already has been on the computer at the station behind the OpenZmeter).

Once installed and licensed, open Protection Suite v5.2.8 on the device being used to control the Doble F6150 power system simulator. You will be prompted to select your language, and then greeted with the following screen:



**Next, you will need to power the Doble F6150 ON by using the switch on top of the simulator before continuing with the software setup. The circuit should be completed from the “Physical Setup” above before powering ON!!!**

To turn on the OpenZmeter V3 GPS, direct your attention to the bottom left corner of the screen at a field called “Battery,” which is populated with a “0” at the moment;



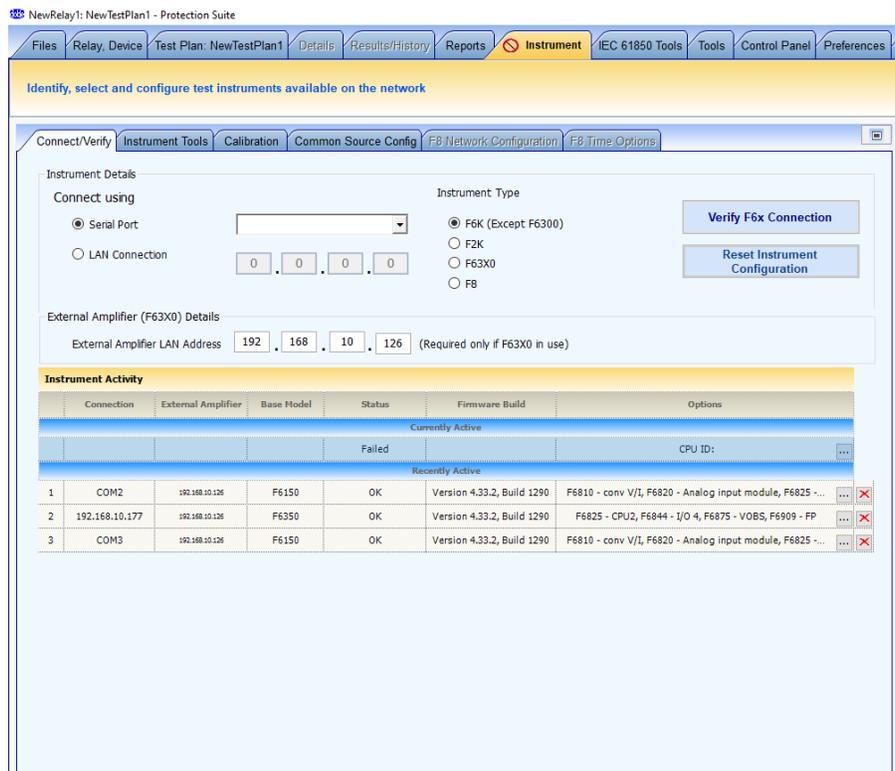
Double-click the “0” in the center and enter “125”. This supply voltage is adequate to turn the meter on before the simulation.

Now click “1” on the right, and the “125” will turn red, indicating that power is being supplied. The meter should then turn on.



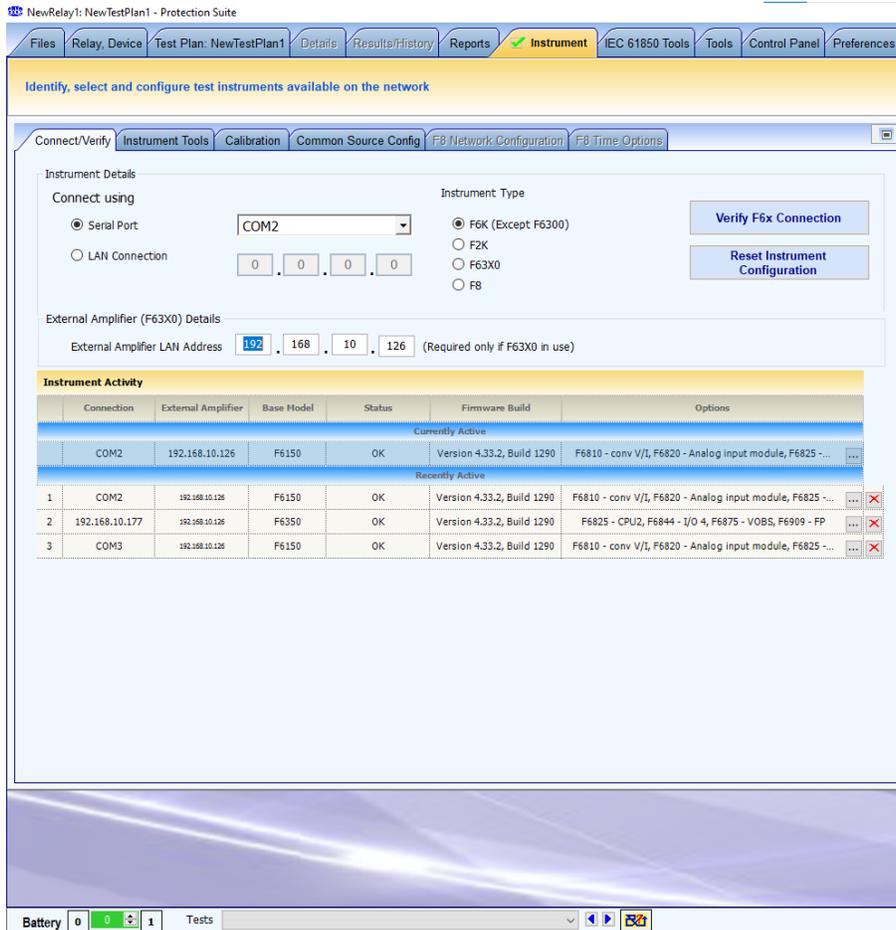
You may hear a tone coming from the OpenZmeter, which means it is booting. It will take about 5 minutes for it to charge, so wait for that amount of time before proceeding. Once 5 minutes have passed, press and hold the small black button at the top right of the meter’s screen. A tone will play, indicating the meter is now turned on.

With the simulator ON, navigate to the “Instrument” tab at the top of the screen and click on it. As shown below, there should be a red symbol next to “instrument” at the top of the window.

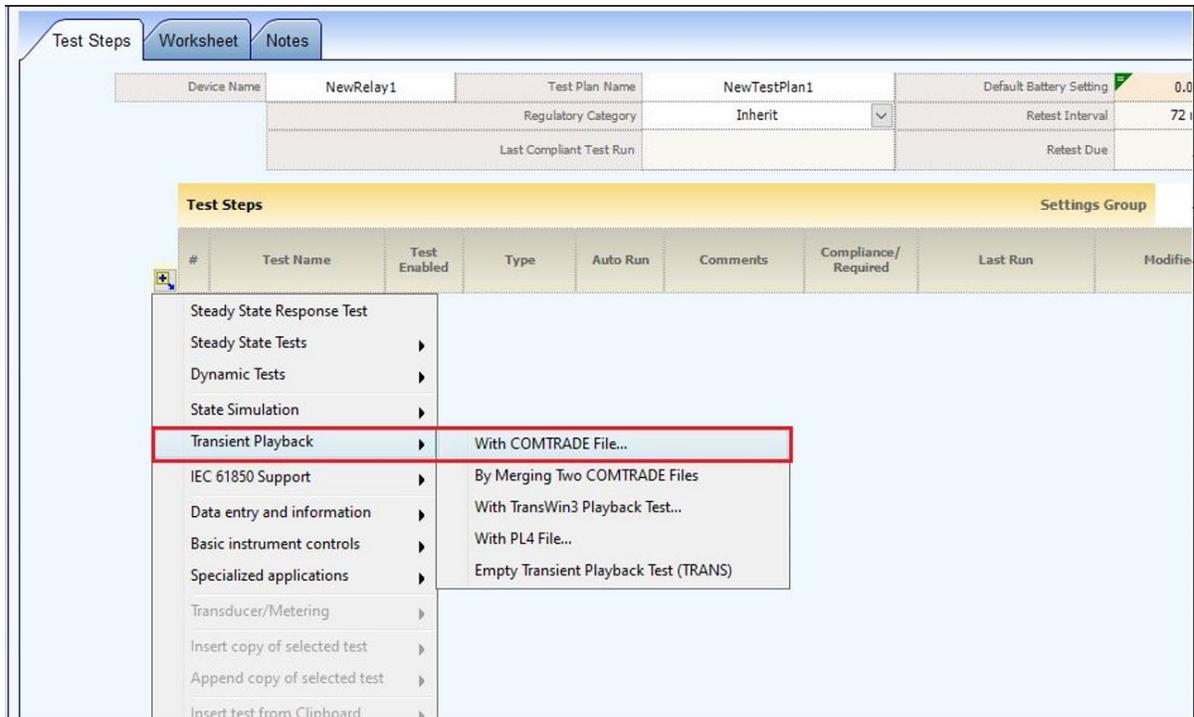


To connect the computer to the Doble F6150 Power System Simulator, click the dropdown box to the right of the “Serial Port” in the above image. After selecting the port to test, click on “Verify F6x

Connection” in the above snippet. If the red symbol at the top doesn't change to a green checkmark, try a different port and test again until it does. When the test is successful, the screen should look like the image below.



The next step is to click “test plan” at the top and click the small box with a “+” and an arrow in it, which is visible in the screenshot below. Next, click “Transient Playback” and “With COMTRADE File...”



Now, an IEEE COMTRADE file may be selected for simulation, which is available under “Desktop.” Select from any of those and click “open.” This file will open at the top of the Doble Protection Suite screen with a name starting with “Test 1.” Click on that tab for the next step.

Now, our current transformer and voltage transformer ratios need to be set so as not to damage the equipment or cause errors. Follow the instructions on the screen below by entering “200” next to “I1,” “I2,” “I3,” and “2000” next to “VA,” “VB,” and “VC.”

Define COMTRADE file channels, inputs, outputs and triggering for Transient Playback test

COMTRADE Sources Worksheet Inputs Timers Outputs States Wave Gen Swing Plots Notes Recording Formula Reference

**COHTRADE Analog Channel Details** Files Info

Channel Index	Channel ID	Formula ID	Phase	Enable Playback	Source	Transformer Ratio		P/S	Maximum Peak Value (Primary)	Maximum Peak Value (Secondary)	Test Values Scaling
						Primary	Secondary				
1	161kV Ipol	Analog1	N	<input checked="" type="checkbox"/>	I1	200	1	P	0.212 kA	1.051 A	1.0
2	161kVBus...	Analog2	A	<input checked="" type="checkbox"/>	VA	2000	1	P	136.716 kV	68.358 V	1.0
3	161kVBus...	Analog3	B	<input checked="" type="checkbox"/>	VB	2000	1	P	138.100 kV	69.05 V	1.0
4	161kVBus...	Analog4	C	<input checked="" type="checkbox"/>	VC	2000	1	P	135.333 kV	67.667 V	1.0
5	161 Bus 2...	Analog5	N	<input type="checkbox"/>		1	1	P	10.822 kV	10821.808 V	1.0
6	848 Shoals...	Analog6	A	<input checked="" type="checkbox"/>	I2	200	1	P	0.808 kA	4.042 A	1.0
7	848 Shoals...	Analog7	B	<input checked="" type="checkbox"/>	I3	200	1	P	2.052 kA	10.259 A	1.0
8	848 Shoals...	Analog8	C	<input type="checkbox"/>		1	1	P	0.995 kA	994.855 A	1.0

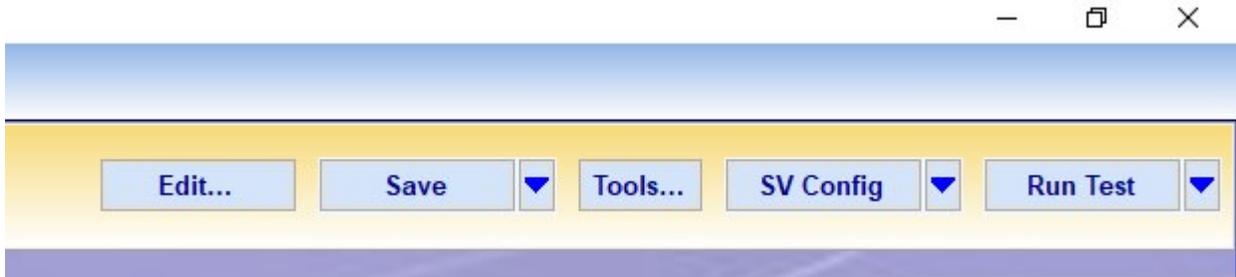
**COHTRADE Digital Channel Details**

Channel Index	Channel ID	Phase	Enable	Output	Normal State
1	161 Ipol OC		<input type="checkbox"/>		0
2	Xbrig fm U2 Fast		<input type="checkbox"/>		0
3	848 Status		<input type="checkbox"/>		0
4	858 Status		<input type="checkbox"/>		0
5	SENS OUT 11A2		<input type="checkbox"/>		0
6	878 Status		<input type="checkbox"/>		0
7	894 Status		<input type="checkbox"/>		0
8	914 Status		<input type="checkbox"/>		0

Select all Select none Select all analog Deselect all analog Select all digital Deselect all digital Hide unused

Divide all the voltage signals by a factor of 2000  
Divide all the current signals by a factor of 200

Once this has been completed, navigate to the top right corner of the screen and click “Run Test”.



When doing this, you may be prompted with a screen asking for credentials, so click “cancel” if this happens. Give the program a few seconds; if it doesn’t start running, click “run” again.

## Appendix B

# Setting Up the OpenZmeter V3 GPS



**Date Issued: 2/20/2024**

**Written by: Kole Hall, Nate Hawkins, & Tyler  
Wolfe-Driver**



## Powering On the OpenZmeter V3 GPS (OZM)

To power the OZM, a DC or AC power supply capable of 60-375  $V_{dc}$  or 60-265  $V_{ac}$  will be needed. ([OZM 3-phase Spec Sheet](#))

Connect wires/terminals to the “power” terminals located on the top of the OZM as shown below:



Figure 1- OZM Power Terminal

With the terminals connected and secured via a screwdriver, the power supply may now be turned on to a value within the tolerable ranges. Once power is provided, the OZM will play a tone as it starts. The device will also emit a red light from inside the housing, visible from the vents on the top and bottom of the meter.

## Bluetooth Networking Connection to the OZM

The OZM may not appear as a visible device ready to connect in Bluetooth settings depending on the machine used. For example, Windows laptops may not see the device, but perhaps a smartphone does. Therefore, two options are provided below for connecting the OZM to a network.

## *Utilizing Laptop*

The same steps in the following section can be used to connect the OZM to the internet. A Bluetooth connection from the laptop to the OZM will be needed, and the laptop's Wi-Fi will need to be disabled. Afterward, the following steps can be taken.

If a user-based network, such as those discussed in the following section, is utilized, the laptop's control panel will be used to find the MAC address with the command “ipconfig /all.” Then, under the section “Ethernet adapter Bluetooth Network Connection:” the “Physical Address” will be the MAC address of the Bluetooth-connected device. The following is a screenshot showing the outputs of the prompt:

```
Ethernet adapter Bluetooth Network Connection:

Media State . . . . . : Media disconnected
Connection-specific DNS Suffix . :
Description . . . . . : Bluetooth Device (Personal Area Netwo
rk)
Physical Address. . . . . : 98-8D-46-72-1D-65
DHCP Enabled. . . . . : Yes
Autoconfiguration Enabled . . . . : Yes

C:\Users\device>
```

## *Smartphone Bluetooth Connectivity*

- This is an example of how the meter appears when it is available for a Bluetooth connection on a smartphone:

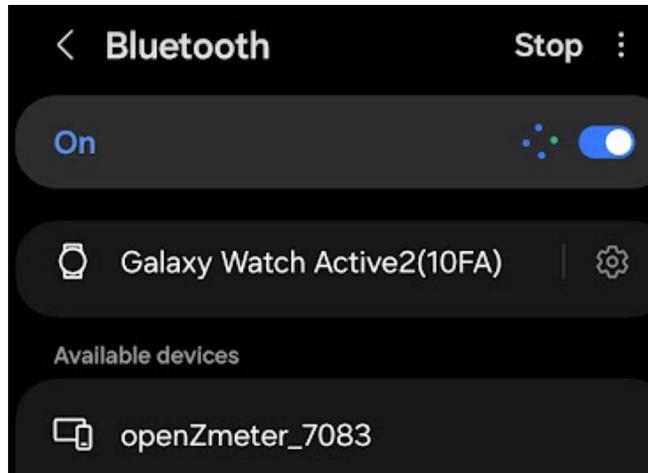


Figure 1 - The OZM appears open for connection via Bluetooth on a smartphone.

- Before connecting, the Bluetooth networking feature can only work correctly if the device connecting to the meter has wifi and mobile data disabled.
- Now, with the OZM connected via Bluetooth as shown below, open any browser and search for “10.0.0.1”.

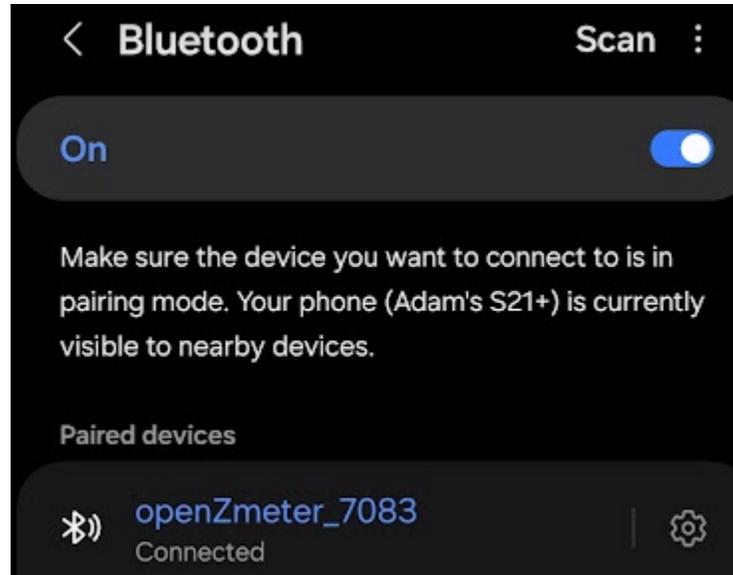


Figure 2 - The smartphone has successfully connected to the OZM.

- When searching for “10.0.0.1,” you will be taken to a loading screen containing the OpenZmeter logo. Stay in this browser and allow the loading to complete.

- Once the loading has finished, you will be prompted with a “Wi-Fi setup wizard,” as shown below:

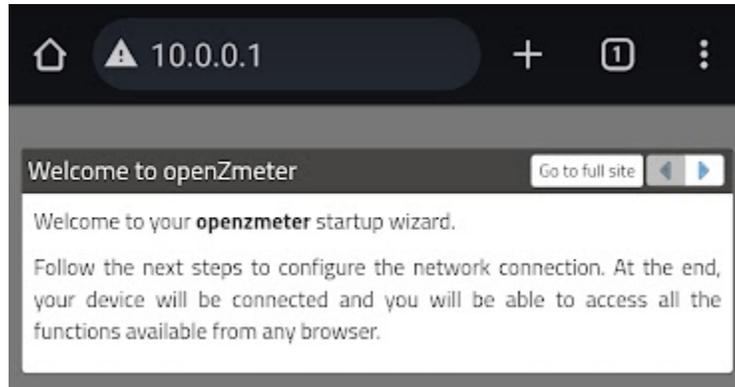


Figure 3 - The wifi setup wizard that appears after 10.0.01 loads successfully.

- Click the rightmost arrow to navigate to the Wi-Fi network selection page.
- Select a “UTC” (Not “UTC Secure”) option. Depending on the Security Standard of the W-Fi (WPA, WEP, or WPA2\_EAP, etc.), the network's security may not allow for direct connection and will need assistance from IT. If the network is not user-based, the credentials may be entered directly into the fields of the selected network, as shown in the next bullet.

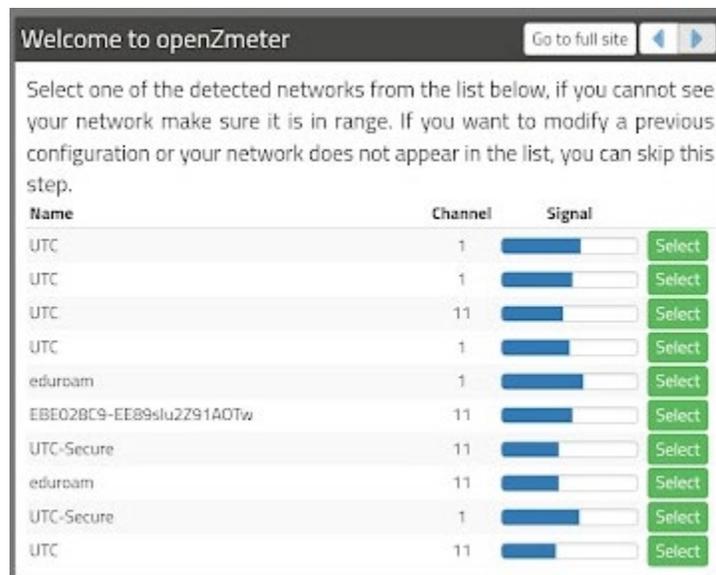


Figure 4 - An example list of available networks to connect the OZM to.

- However, if it is user-based, such as Enterprise WPA2 (WPA2\_EAP), IT will need to be contacted on what to enter into the fields, and possibly the MAC address of the OZM will be required.
- The following discusses how to obtain a Mac address....
- After the MAC address is secured, the next step is to contact the respective IT department of the network to which the OZM will be connected. A static, discoverable IP will be needed so that connection can be ensured whenever trying to access the OZM. However, in the meantime, the network that is going to be used for the OZM can be selected, and the following step can be taken until the MAC address is verified.
- Once you have selected one of the network options, enter the following info corresponding to that network. Once again, these entries depend on the network's security.

The screenshot shows the 'Welcome to openZmeter' interface. It contains several input fields and dropdown menus:
 

- NTP server:** A text input field containing 'time.utc.edu'.
- SSID:** A text input field containing 'UTC'.
- Mode:** A dropdown menu currently set to 'NONE'.
- IP Mode:** A dropdown menu currently set to 'DHCP'.
- ESSID Key:** A text input field with a lock icon on the right, indicating it is a password field.

 In the top right corner, there is a 'Go to full site' button and navigation arrows.

Figure 5 - Information fields must be filled out to connect to the selected network successfully.

Once all fields are completed, click the rightmost error to test the connection.

- The connection test will begin automatically, lasting only a few seconds before indicating a failed test or successful completion. When the test is done successfully, a message such as the following will be displayed:



Figure 6 - The OZM has successfully connected to the OZM.

- Once this screen is obtained, the “Device IP address” will need to be noted, and “Go to full site” will need to be selected.
- (IF DESIRED) When accessing the full site, the next step is to create an administrator account and change the password, email, and anything else desired. Multiple accounts can be given to different device users.
- After the administrator account has been updated, the “Device IP address” can be entered into any device URL if desired. The setting up of channels discussed in the next section can begin. Note: if the administrator account has not been updated, the user and password will be admin/admin. If it has been updated, enter the selected username and password.
  - If a user-based network is utilized and the device's MAC address has not been updated to a static, discoverable IP address, the device cannot be connected to the network without a local Bluetooth connection.

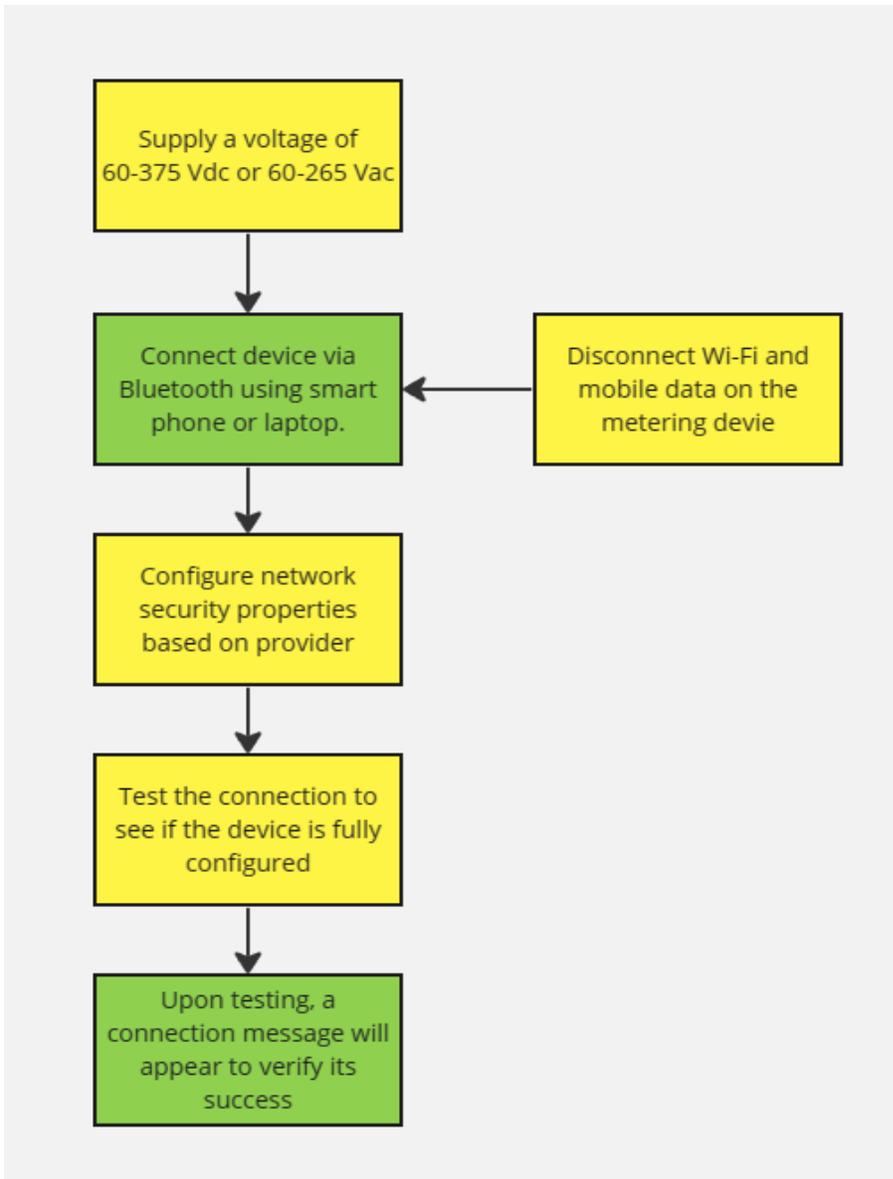
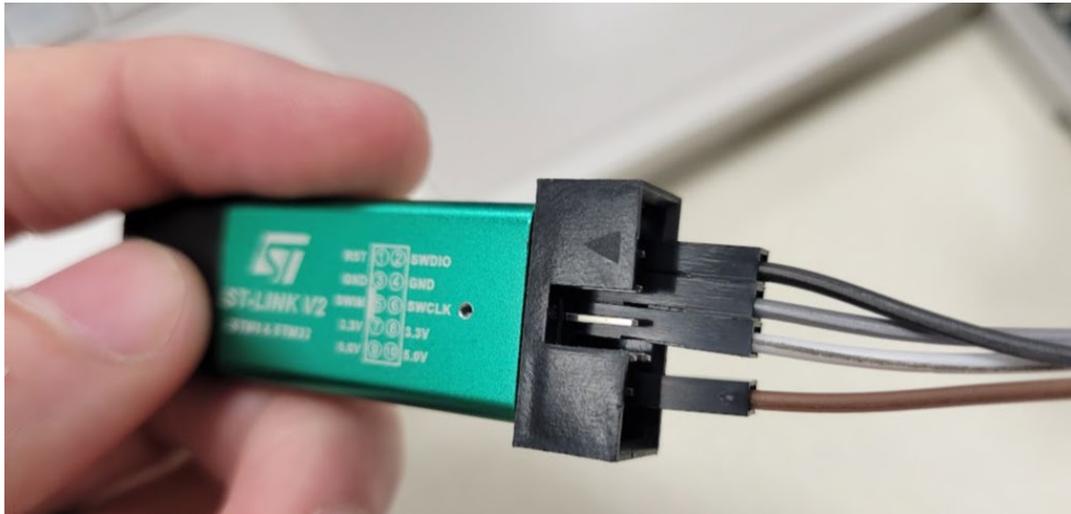


Figure 7: OpenZmeter network connection process

## Appendix C

The following procedure was developed following instructions sent via the OpenZmeter staff. Those instructions are included in the Google Drive folder associated with the project and are titled “Guia de actualizacion.”

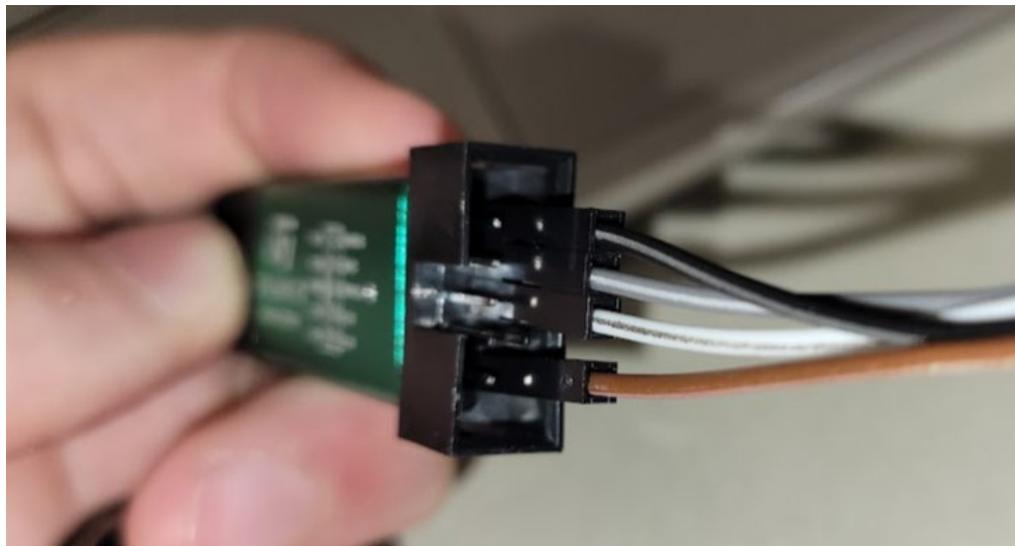
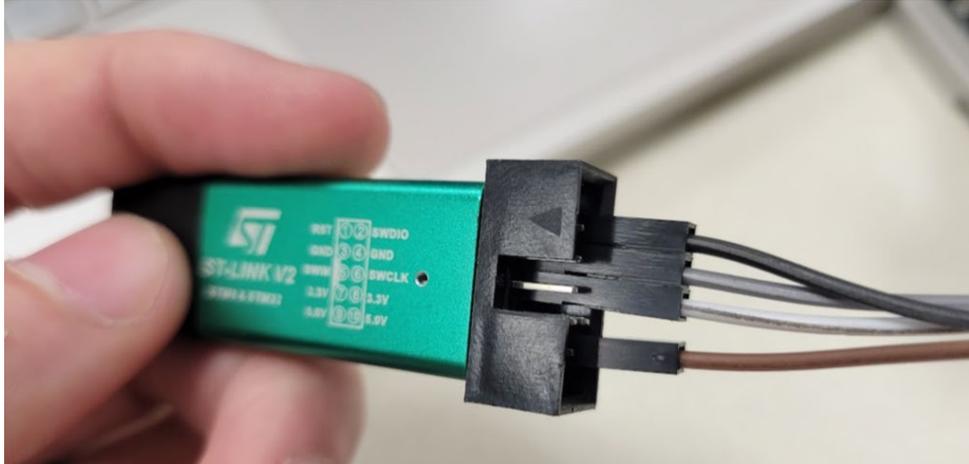
- Received the programmer from the OZM staff (ST-LINKV2) shown below.



- The update on the link device requires the installation of stsw-link004 for Windows, which is a free application [here](#). You must create an account to download it, but the setup afterward is simple.
- Before proceeding, you will need to have received the firmware update from the inventors. For stsw-link004, compatible formats are .bin and .hex files.



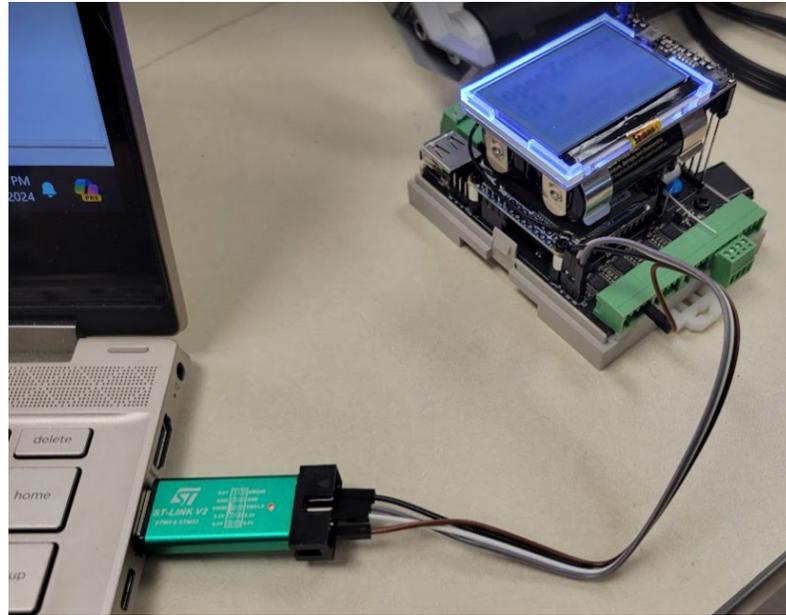
- Next, we need to wire the ST-LINK:
  - On the programmer, connect to pins “SWDIO,” “GND,” “SWCLK,” and “5V”.



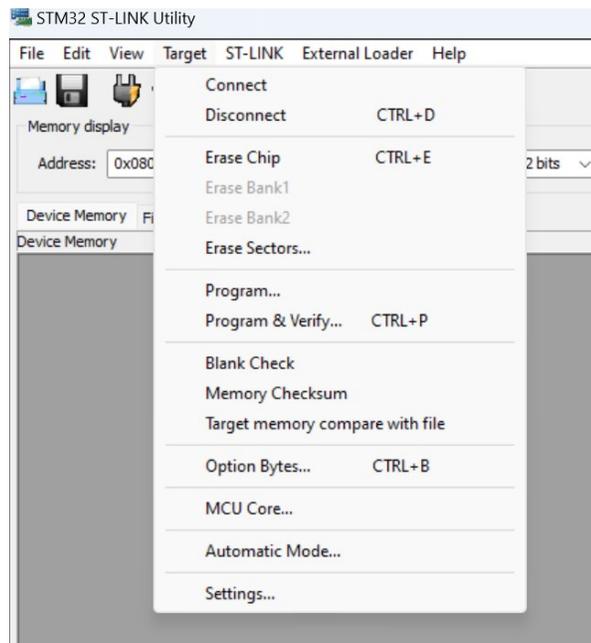
- For the OpenZmeter, you must first remove the cover. There are exposed tabs on the sides, but you don't need to press those inwards. Instead, there are small gaps on either side of the bottom just below the pins on the side. Using your fingernails, pry the case off using the gaps on the left and right sides of the bottom.
- Once the cover is removed, this is how the meter should be wired:
  - Connect the wires to the STLink programmer as shown in the picture. (GND, DATA and CLK goes to the 3 pin connector. +5v goes to the +5v pin in current probe connector)



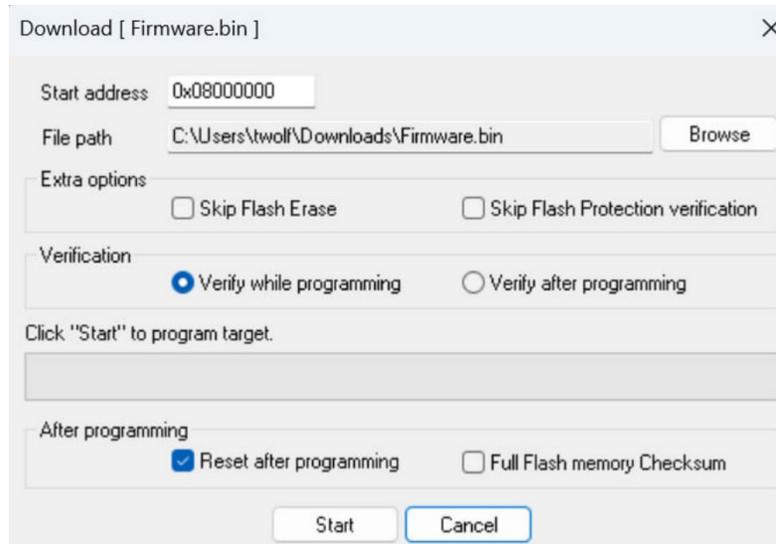
- Now connect the ST-Link to the USB port of a laptop containing the stsw-link004 application.



- This concludes the wiring portion of the update.
- In the stsw-link004 application, click “target” at the top, then “program & verify”:



- Now, click browse and select the firmware update file in one of the compatible file types. Once it's uploaded, click “start,” and the update will complete quickly.



- Now that the firmware update is complete, you may close the application, un-wire the programmer, and return the case to the OpenZmeter.