INTERFACING A PICO GRID TO A MICROGRID

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Abstract - This investigation aims to seamlessly integrate a Pico Grid with a Micro Grid to optimize surplus energy usage. The system incorporates automation, utilizing microcontrollers and communication devices for real-time power monitoring and control. Components like the DC Power Supply, DC-DC Boost Converter, Grid Tie Inverter, and ESP8266 WIFI Board are pivotal. The Pico Grid harnesses electricity from local sources, while the Boost Converter elevates voltage for compatibility with subsequent components. The Grid Tie Inverter converts DC to AC, synchronizing it with the grid. The ESP8266 enables wireless communication and data exchange. Results demonstrate successful scalability and effective control algorithms.

Key words: DC Power Supply, DC-DC Boost Converter, Grid Tie Inverter, and ESP8266 WIFI Board.

1. INTRODUCTION

In modern energy systems, the integration of renewable energy sources and smart grid technologies is pivotal in addressing challenges related to energy security and sustainability [2]. With persistent energy shortages and escalating demands, this investigation aims to bridge the gap between Pico Grids and Micro Grids, ultimately enhancing the efficient utilization of surplus energy. This report is structured to provide a comprehensive project overview. It begins by examining the system's components and their respective functions. The following sections delve into the system's operation, including automation and control strategies. Results and findings will be presented to illustrate the system's scalability and its responsiveness to control algorithms. Following this, critical analysis and recommendations will be provided, shedding light on the implications and prospects of this pioneering energy integration system.

2. BACKGROUND

With chronic power shortages, load shedding, and rising energy demands, South Africa faces numerous challenges in ensuring a consistent and reliable energy supply. Smart grids offer a transformative path toward energy resilience and self-sufficiency, empowering communities to generate, store, and efficiently use their own electricity [1]. In this vision of the future, not only will load shedding become a relic of the past, but communities will have the capacity to take control of their energy needs, reduce costs, and even profit from the surplus energy they produce. This evolution hinges on the efficient extraction of surplus energy from localized sources like pico-grids, seamlessly redirecting it into larger micro-grids. This not only guarantees effective energy utilization but also opens avenues for monetizing excess electricity, benefiting households and the wider community.

2.1. *Objectives*

The main objective of this investigation is to create a system that seamlessly connects a Pico Grid with a Micro Grid, facilitating efficient use of excess power generated by the Pico Grid. Automation plays a key role in achieving this goal, using microcontrollers and communication devices for real-time power monitoring and control. The project also involves data collection, control algorithm design, and a reduction in manual intervention, all contributing to a more sustainable and responsive energy system.

2.2. *Existing Solutions*

i. Smart Grid Integration

Smart grid technologies play a crucial role in enabling the seamless integration of distributed energy resources, including pico-grids. These solutions leverage advanced communication and control systems to optimize energy generation, consumption, and distribution [1].

ii. Energy Management Systems (EMS)

EMS solutions provide comprehensive control and optimization of energy resources within a microgrid or local energy system. They enable effective management of various energy sources, including renewable generation, and facilitate grid-tie operations [2].

iii. Power Electronics and Converters

Advanced power electronics components, such as inverters and converters, have been pivotal in improving the efficiency and reliability of grid-tie operations. These technologies ensure that the energy generated by pico-grids is compatible with the main grid infrastructure [9].

3. SYSTEM OVERVIEW

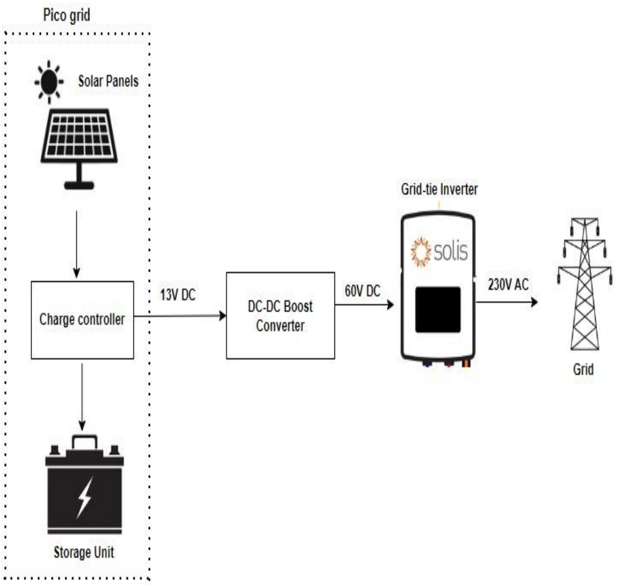

Figure 1: System Overview

3.1. *PicoGrid* – A small-scale electrical power system that generates and distributes electricity from local sources like solar panels, wind turbines, and generators. It includes energy storage units (batteries) to store excess energy during low-demand periods. Excess energy is determined by monitoring the state of charge (SOC) of the energy storage system [4].

3.2. *DC-DC Boost Converter*: This electronic device plays a vital role in boosting the voltage of the low-voltage DC input from renewable sources in pico grids. It ensures a stable power supply for subsequent components like the grid-tie inverter, even when the input voltage is low.

3.3. *Grid Tie Inverter*: The grid-tie inverter performs the crucial task of converting the DC voltage from the renewable energy source to AC voltage that is synchronized with the grid. The inverter ensures that the AC voltage it produces matches the voltage and frequency of the electrical grid, allowing for seamless integration. The Solis Inverter is integrated with a datalogger (with Modbus Protocol), which facilitates wireless communication between the inverter and external systems. It can include data monitoring, remote control, and potential integration with smart home or building automation systems. Additionally, it has an app that allows consumers easy control of the inverter (see Appendix E). The Modbus protocol enables the inverter to exchange data with other devices on the network [6].

3.4. *ESP8266 WIFI Board:* The ESP8266 is configured to connect to a local WiFi network. This enables it to establish communication with other devices on the network or with external servers [5]. The ADC pin on the ESP8266 WIFI Board allows it to read analog voltages. It converts a continuous voltage level into a corresponding digital value that the microcontroller can process. The ESP8266 can be programmed to create a local server using Arduino IDE, which waits for requests for voltage data from connected devices, such as a Python script.

3.5. *Microgrid*: A localized energy system that can operate independently or in coordination with the main electrical grid. It incorporates various energy resources, both renewable and conventional, to provide reliable power to specific areas. Excess energy from a pico grid contributes to grid stability during peak demand or when renewable sources fluctuate, requiring advanced control systems and communication protocols for effective power management.

4. SYSTEM OPERATION

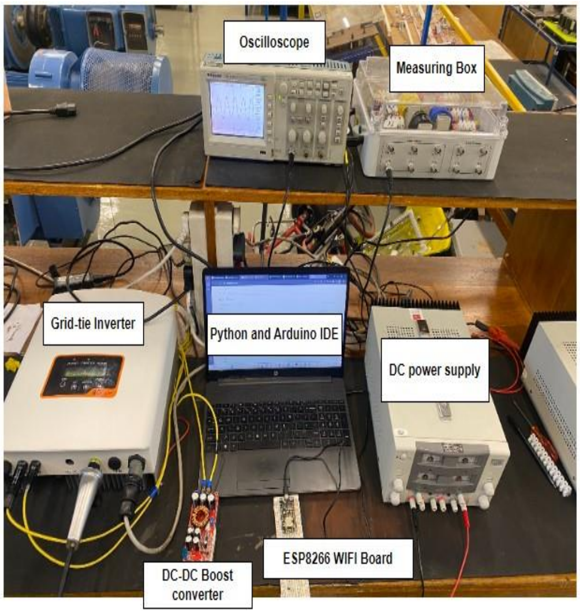

Figure 2: Laboratory setup

The system initiates by drawing power from a simulated pico-grid through a DC power supply, replicating a standard pico-grid setup. This low DC voltage is then elevated to a minimum of 60V DC using a DC-DC boost converter. This conversion requires 0.8 A from the power supply, transforming the voltage from 13V to 60V with a 95% efficiency. The Grid-tie inverter (Solis 700W Mini 4G Single Tracker) receives this elevated 60V DC and converts it into high-voltage AC, making it compatible with the main grid (specification of the grid 50Hz and 230V AC). This functionality was confirmed through a validation test using an oscilloscope, verifying that the grid-tie inverter effectively transforms the DC input voltage into AC, aligning it with the main grid's specifications (see Appendix C). The inverter includes a feature that allows it to feed power into the grid only when the grid is active this is known as Anti-Islanding Protection [9].

4.1. *Excess energy extraction*

The high voltage state observed within the pico-grid, ranging between 13-14V, strongly indicates the presence of excess energy within the system, as corroborated by findings from Iradukunda.D, [4]. This insight serves as the foundation for implementing inverter maximum power point tracking (MPPT) techniques, ensuring optimal energy extraction. In-depth investigations are conducted to discern the response of the inverter to increased demand and to devise strategies that prevent excessive utilization of the pico grid's energy reserves. One of the central challenges encountered in the extraction of excess energy pertains to the inherent limitations of the DC-DC boost converter. As a mitigative measure, a higher-rated power supply is introduced to assess the system's scalability and its capability to accommodate increased power inputs.

4.2. *Controlling the inverter using Modbus Protocol*

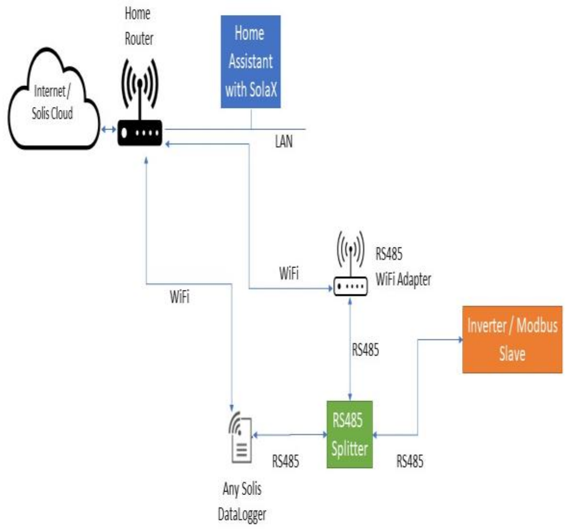

Figure 3: Solis Inverter Modbus Block Diagram [10]

The Modbus protocol, a widely used standard in industrial automation, governs the structure and interpretation of data exchange. In this integration, it operates in a master-slave configuration. The master, represented by the computer or microcontroller, sends requests to read or write data, while the inverter, serving as the slave, responds to these requests. Critical to successful communication is the configuration of RS-485 parameters. Baud rate, data bits, stop bits, and parity settings are harmonized between the master and slave devices, ensuring seamless data transmission [6]. Python, selected for its versatility and extensive library support, is employed to execute Modbus communication. The pymodbus library is instrumental in this process. Python scripts are utilized to initiate Modbus requests, allowing the master device to read or write specific registers on the inverter.

The Solis cloud platform provides a centralized interface for monitoring and managing inverters. Integration with this platform is achieved through API access or other integration methods offered by Solis. Appendix E shows diagrams of the Solis cloud application after a successfully connection.

Establishing a stable local Wi-Fi connection proved challenging due to network interference from neighboring devices. This interference occasionally led to dropped connections and disrupted data transmission. Remediation strategies included relocating the Wi-Fi module to a less congested frequency band and implementing signal amplification techniques [10].

4.3. *Automation*

The automation of the system was initially challenging, with an Arduino Nano used for voltage measurement from the pico grid, connected to an ESP8266 WIFI module. Configuring the Tx and Rx pins of the ESP8266 proved challenging and required more time, Appendix D shows the connections followed. However, upgrading to an ESP8266 WIFI board with a 10-bit ADC pin simplified the setup and was time efficient.

a. Pico grid voltage monitoring

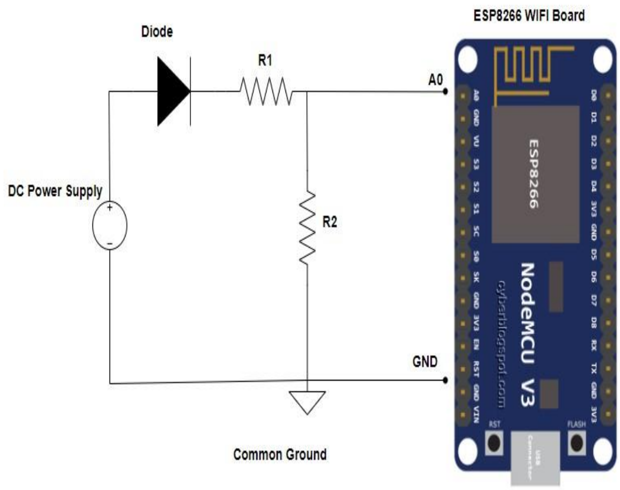

Figure 4: Voltage measuring circuit.

Figure 4 shows the connection of the voltage monitoring circuit. The diode is employed to block any high current that might flow from the power supply to the ESP8266 WiFi board. It serves as a protective component, preventing excessive current from damaging the sensitive electronics of the ESP8266. Diodes allow current to flow in only one direction, ensuring that the current doesn't pass back into the ESP8266. R1 and R2 are resistors that are configured as a voltage divider. The purpose of this arrangement is to reduce the voltage from the DC power supply to a level that the ESP8266 WiFi board can safely and accurately measure. According to the datasheet the ESP8266 board is designed to handle inputs up to 3.3V.

The voltage division formula is:

$$V_{out} = Vin \times \frac{R_2}{R_1+R_2} \quad (3)$$

The ESP8266 is equipped with an Analog-to-Digital Converter (ADC) pin, A0, which can measure analog voltage levels. The ADC pin is connected to the junction point of R1 (20kΩ) and R2 (10kΩ). By reading the voltage at this point, the ESP8266 can determine the voltage provided by the DC power supply.

Prior to implementing certain measures, we observed a slight discrepancy in the ADC readings. This discrepancy was attributed to a combination of factors, including the resistor tolerances. This was adjusted by using the value that the ADC pin read when the supplied voltage was 0 and making it our reference voltage value on the code. Appendix G documents the voltage measurement code.

b. Communication

The ESP8266 WIFI board serves as the central controller and communication hub, establishing a connection to the local Wi-Fi network and creating a server for receiving voltage data. A local host, EnergyLab WIFI, was used, and both the inverter and the ESP8266 WIFI board were connected to it, each with its specific IP address. An automation sequence is detailed, explaining how the system operates when Python scripts send requests to the local host. Figure 5 shows the operation of the automated system.

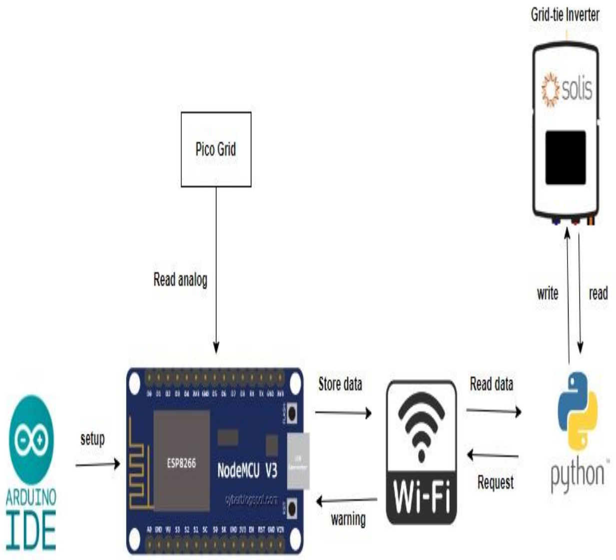

Figure 5: System control and automation

The automation sequence unfolds as follows:

i. Looking at Figure 5 every time the Python script sends a request to the local host, the ESP8266 Wi-Fi board receives the request, executes the specified code, and subsequently returns the result as an HTTP request.

ii. The Python script, in turn, interprets this data and employs it to communicate with the Solis Grid-tie inverter through the Modbus protocol and RS-485 RTU (Remote Terminal Unit).

iii. It writes to the inverter's registers, providing the necessary instructions to initiate the generation and feeding of power into the main grid.

4.4. Python Interface

The control algorithm regulates the inverter's power output based on the available excess energy, ensuring that the inverter does not exceed the system's capacity and avoids overloading.

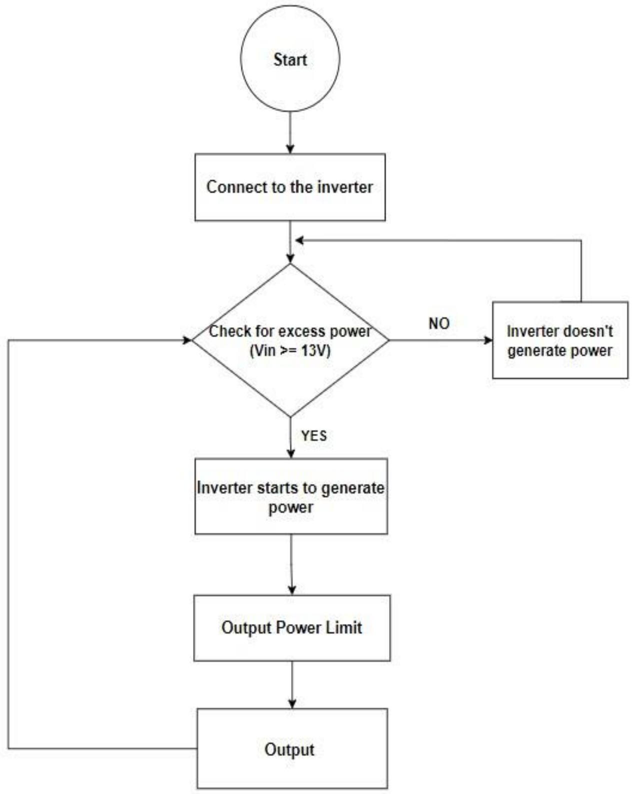

Figure 6: Control Algorithm

The algorithm continuously monitors the pico grid's voltage, ensuring it falls within the specified range of 13-14V. If the pico grid's voltage is within the specified range, the algorithm instructs the grid-tie inverter to start generating power for the main grid. If not, it continues monitoring. When the inverter starts generating power, the algorithm assesses the quantity of excess energy available and limits the inverter's output accordingly to prevent overloading and minimize reliance on the pico grid.

$$Power_{limit} = \frac{Excess\ DC\ Power}{800} \times 10000 \quad (2)$$

After excess energy injection, a delay of about 60 seconds allows the pico grid to generate power before the inverter resumes its operation. To prevent the inverter from drawing power from the pico grid when no excess energy is available, the algorithm simulates the main grid's status by writing to the inverter's grid register (register address – 3006 this hexadecimal value 0xDE). The code implementing these functions can be found in Appendix F.

5. RESULTS AND FINDINGS

5.1. *Scalability*

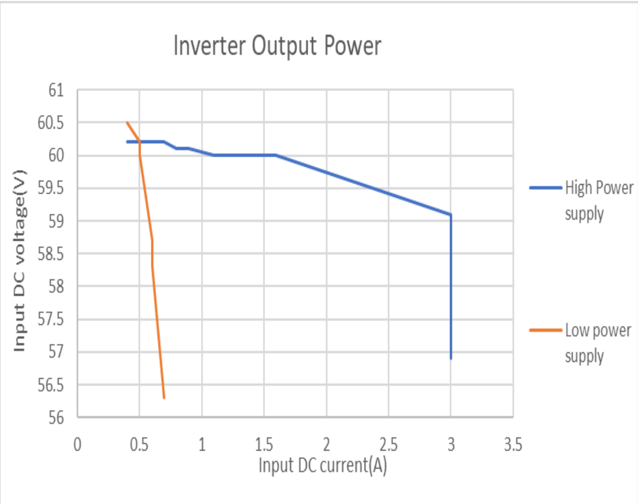

Figure 7: Inverter Output Power

To assess the scalability of the system, a low-power supply (39W) is contrasted with a higher-rated power supply (180W). The inverter's output power is incrementally adjusted to ascertain the precise point at which each supply approaches overloading. This demonstrates the inverter's Maximum Power Point Tracking (MPPT) capability. MPPT prompts both power supplies to potentially experience overloading, as it attempts to draw a maximum of 800W. The trend for the low-power supply (depicted in orange) rapidly begins to decline when the power demand on the grid-tie inverter surpasses its capacity, triggering a heightened draw of current from the DC-DC boost converter. Consequently, the voltage supplied by the power source starts to decrease.

$$\Delta V = I \times R_{internal} \quad (1)$$

Equation 1 illustrates that as the current increases, it induces a voltage drop across the internal resistance of the supply, resulting in a reduction in the supplied voltage. The trend for the high-power supply follows a similar pattern, due to its higher capacity, it takes longer to experience overloading compared to the low-power supply. From the graph, we observe that the high-power supply (depicted in blue) experiences a gradual decrease. This is attributed to the fact that the power supply can only deliver approximately 22.5% of the inverter's maximum capacity. Once it reaches 59V and 3A, which is its maximum supply capability, the power supply enters an overloading state and attempts to decrease the voltage to maintain a constant current value.

5.2. *System Response to Control Algorithm*

Table 1: Output power of the inverter before the control algorithm

Available DC Power(W)	Extracted AC Power (W)
40	52
38	39
38	37
40	39
54	52
24	23
40	39
18	17
54	52

Table 1 displays data representing the inverter's power output before implementing a control algorithm. The data reveals significant variations in the extracted AC power despite relatively stable levels of available DC power. This variance suggests that the inverter may not be exclusively utilizing excess energy but may also draw power from the pico grid itself, potentially due to its maximum power point tracking (MPPT) behavior [9]. This highlights the necessity of a control algorithm to precisely manage the inverter's operation, prioritizing excess energy utilization while minimizing dependence on the pico grid during surplus energy periods.

Table 2: Output power of the inverter after the control algorithm

Available DC power (W)	% Max output power(800W)	Extracted AC power(W)
39	4.87	38
38	4.75	37
38	4.75	37
40	5	39
39	4.87	38
39	4.87	38

Table 2 showcases the inverter's power output after the implementation of a control algorithm. The data indicates a significant reduction in the variance between available DC power and extracted AC power with 97% efficiency, signifying the control algorithm's success in aligning the inverter's behavior with the goal of prioritizing excess energy utilization. This demonstrates a notable improvement in system efficiency and sustainability, as the inverter now draws power more in line with the available surplus energy, reducing reliance on the pico grid's energy.

6. CRITICAL ANALYSIS AND RECOMMENDATIONS

The system shows impressive scalability but also exposes limitations in the DC-DC boost converter, particularly in handling rapid power supply fluctuations affecting voltage levels. To overcome this technical challenge, it is advisable to explore advanced DC-DC converters with improved efficiency and power handling capabilities. Additionally, implementing a time-aware control algorithm is recommended. This algorithm should not only assess excess energy availability but also consider the time required to inject it into the grid and the current grid load. Such an approach would further optimize power generation and distribution, enhancing the system's responsiveness to real-time energy fluctuations and needs.

7. PROJECT MANAGEMENT

This section outlines the cost breakdown of the system components, providing transparency in budget allocation.

Table 3: Cost of the system

Components	Total cost
DC-DC Boost Converter	R350
EPS8266 WIFI Board (2)	R557.98
Solis Grid-tie inverter 0.7kW 4G Single Tracker	R4189
Resistors	R1.40

The project budget was R1500 and since the inverter was provided by the Gemini Lab the total cost inquired was R909.38 and did not exceed the budget.

8. CONCLUSION

This investigation focused on integrating a Pico Grid with a Micro Grid to harness excess energy for efficient utilization. Advanced components like the DC-DC boost converter and Grid-tie inverter were instrumental in ensuring stable power flow. Automation, facilitated by the ESP8266 WIFI board and Python scripting, streamlined real-time decision-making. Scalability testing demonstrated the system's adaptability, while the control algorithm significantly improved energy optimization. Future recommendations, including a time-aware control algorithm, promise even greater efficiency. This project contributes to building a sustainable and resilient energy ecosystem.

9. ACKNOWLEDGEMENTS

The author would like to acknowledge his partner S'phesihle Mnyandu for his hard work and insight on the project. The guidance of Prof. Cronje, our supervisor, is much appreciated.

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APPENDIX A

GROUP WORK REFLECTION

Working together on this investigation was a rewarding experience. Our complementary skills and expertise greatly contributed to the success of the project. While I was delved into the technical aspects, such as programming and hardware implementation, and my partner focused on data analysis and circuit building. This division of tasks allowed us to cover a wide range of responsibilities efficiently. Each team member brought unique strengths to the table. Since I am good in programming and had a deep understanding of the Modbus protocol, establishing communication with the inverter didn’t really take us a long time. My partner was really good connecting circuits data analysis, providing critical insights into the scalability and performance of the system. This collaborative dynamic enhanced the overall quality of our investigation.

One of the main challenges we encountered was during the automation phase, particularly in configuring the ESP8266 WIFI module. There was limited online information available, which required additional time and troubleshooting. Additionally, we faced some initial difficulties in integrating the control algorithm with the inverter's behavior, which necessitated thorough testing and refinement.

Through this collaboration, I learned the importance of effective communication and task allocation. Regular check-ins in the Gemini Lab with our supervisor and a clear description of responsibilities ensured that we stayed on track and maximized our productivity. Additionally, we gained a deeper understanding of the Modbus protocol and its applications in energy systems, which will be invaluable for future projects.

Table A1: Task Allocation

Task	Aobakoe Nke	S’phesihle Mnyandu
Project research	√	√
Laboratory setup	√	
Modbus communication	√	√
Python Code	√	
Arduino IDE code		√
Voltage Monitoring circuit	√	√
Project testing and investigation	√	√
Control algorithm		√

APPENDIX B

INTERFACING A PICOGRID TO A MICROGRID

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Abstract: This project investigates the process of interfacing a low-energy DC Pico grid with an AC micro grid in South Africa, utilizing solar equipment and grid-tie inverters. The objective is to transfer excess energy generated by the Pico grid into the higher-energy micro grid, optimizing energy utilization and promoting grid stability. The project entails a detailed analysis of system components, interface design, control and protection mechanisms, economic and environmental impact assessment, a localized case study on South Africa, and experimental validation. The outcomes contribute to sustainable energy practices, renewable energy integration, and grid efficiency improvement, with potential for replication and future research in grid integration.

1. INTRODUCTION

South Africa has been faced with energy shortage crisis in the recent years, which has led to an increase in the demand for renewable energy sources. The output voltage of renewable energy sources such as the PV module is small when compared with the voltage demanded by the AC loads. Therefore, voltage needs to be boosted up and inverted [9]. This makes it important to study methods, which can be used to extract maximum energy from the renewable energy sources and then exporting it to the grid. This leads to the development of power electronics equipment to maximize energy harvesting from renewable energy sources [9]. The aim of this report is to discuss the project plan for the investigation into the interfacing a low energy (DC Pico grid) to a higher energy (AC micro grid).The output of the pico-grid (low DC) is converted to a desirable form by using DC-DC converter [8]. Further DC voltage is converted to AC (Higher energy) using DC-AC grid tie inverter [8]. The maximum power point tracking (MPPT) is used to continuously track down energy variations in the Pico grid and extract maximum available power [8].

2. BACKGROUND

This project investigates the process of interfacing a low-energy DC Pico grid with an AC micro grid in South Africa, utilizing solar equipment and grid-tie inverters. The objective is to transfer excess energy generated by the Pico grid into the higher-energy micro grid, optimizing energy utilization and promoting grid stability. The project entails a detailed analysis of system components, interface design, control and protection mechanisms, economic and environmental impact assessment, a localized case study on South Africa, and experimental validation. The outcomes contribute to sustainable energy practices, renewable energy integration, and grid efficiency improvement, with potential for replication and future research in grid integration. To bridge the gap between these low-energy DC Pico grids and the high-energy AC micro grids, an interface is required to enable the transfer of excess energy generated by the Pico grids into the main grid. This integration can help optimize energy utilization, reduce dependency on non-renewable sources, and enhance the overall stability and reliability of the electricity supply. Solar equipment, such as photovoltaic (PV) panels, plays a crucial role in DC Pico grids as they harness the sun's energy to generate electricity. Grid-tie inverters are essential components that convert the direct current (DC) produced by solar panels into alternating current (AC) that can be synchronized with the AC micro grid [4]. These inverters also enable bidirectional power flow, injecting surplus energy from the Pico grid into the main grid. South Africa, with its abundant solar resources and a strong push for renewable energy, provides an ideal context for exploring the interface between DC Pico grids and AC micro grids.

3. Literature Review

3.1. Overview of Pico grid and Micro grid

DC Pico Grids

A DC Pico grid is a localized electricity distribution network that operates on a low energy level. It typically consists of small-scale renewable energy sources, such as solar panels or wind turbines, for power generation [1]. Pico grids are often deployed in rural or remote areas where extending the main grid infrastructure is challenging or uneconomical. These grids are designed to meet basic energy needs, such as lighting, phone charging, and powering small appliances. They are characterized by their small capacity and limited scale.

AC Micro Grids

In contrast to DC Pico grids, AC micro grids form the backbone of the centralized electricity distribution system. They operate at a higher energy level and serve a larger area with a mix of consumers and generators. Utility-scale power plants, including conventional fossil fuel-based generators as well as renewable energy sources [3], typically power micro grids. They can be connected to the main grid or operate in an islanded mode, where they can function independently during grid outages or in areas with unreliable grid supply.

3.2. Grid integration

Grid integration and energy management are essential aspects of integrating renewable energy systems, such as DC Pico grids, with existing AC micro grids. These concepts encompass various techniques and strategies aimed at optimizing energy utilization, maintaining grid stability, and ensuring efficient operation of the integrated systems [2].

Grid integration involves the seamless connection and coordination of distributed energy resources (DERs) with the main grid infrastructure. It encompasses the technical, operational, and regulatory aspects necessary for the smooth integration of renewable energy sources into the existing grid. Ensuring that the electricity generated by the DERs meets the quality standards required for safe and reliable operation of the grid. Implementing control mechanisms to maintain stable voltage and frequency levels within acceptable limits. Managing bidirectional power flow between the Pico grid and the micro grid, allowing for the injection of excess energy or drawing energy from the main grid as needed.

Achieving synchronization between the frequency and voltage of the Pico grid and the micro grid to enable seamless power transfer and coordination.

Implementing mechanisms to detect and prevent islanding (i.e., the Pico grid operating in isolation during grid outages), as well as ensuring grid stability, overcurrent protection, and fault detection.

3.3. Solar equipment in Pico grid

Solar equipment, especially photovoltaic (PV) panels, plays a crucial role in DC Pico grids by harnessing the sun's energy to generate electricity. PV panels serve as the primary energy source in Pico grids. They consist of multiple solar cells made from semiconductor materials, typically silicon. When sunlight strikes the solar cells, it excites electrons, creating a flow of DC electricity. Key aspects of PV panels in Pico grids include:

- Capacity and Configuration: The capacity of PV panels determines the maximum power they can generate. Pico grids employ PV panels with an appropriate capacity based on energy demand and available solar resources in a specific location. The configuration of PV panels depends on factors such as available space, tilt angle, shading considerations, and desired electrical output.
- Efficiency and Performance: PV panel efficiency refers to the conversion efficiency of solar energy into electricity. Higher efficiency panels can generate more electricity for a given amount of sunlight. Performance factors, such as temperature coefficient, degradation rate, and tolerance to shading, can also affect the overall energy output of the PV system.
- Mounting and Orientation: PV panels are mounted on structures like rooftops, ground-mounted racks, or poles to maximize sun exposure. The orientation and tilt angle of the panels are optimized to capture the maximum sunlight throughout the day, considering the specific latitude and local solar angles.

Balance of System Components: In addition to PV panels, Pico grids incorporate other balance of system (BoS) components to ensure the proper functioning and safety of the solar equipment. Charge controllers regulate the charging and discharging of batteries in systems that include energy storage. They protect the batteries from overcharging or over-discharging, ensuring their longevity and efficient operation. Energy storage is often incorporated into Pico grids to store excess energy generated by the PV panels for later use when solar generation is insufficient or during peak demand. Batteries, such as lead-acid or lithium-ion batteries, store the energy and supply it when required. Proper wiring and connectors are used to interconnect the PV panels, charge controllers, batteries, and other system components, ensuring efficient and safe electrical connections.

Pico grids may include monitoring and control systems to monitor energy generation, battery status, and system performance. These systems provide valuable insights into energy consumption patterns and enable efficient management of solar equipment. Efficient utilization of solar equipment in Pico grids requires careful system design, considering factors such as energy demand, solar resource availability, panel capacity, and system configuration. By leveraging solar energy, Pico grids can provide clean and sustainable power to meet the basic energy needs of remote or underserved areas while reducing dependence on non-renewable energy sources.

3.4. Grid-tie Inverters

Grid-tie inverters play a vital role in integrating DC Pico grids with AC micro grids. These inverters convert the direct current (DC) electricity generated by solar equipment, such as PV panels, into synchronized alternating current (AC) that matches the AC micro grid. Their primary function is to convert the DC power from solar equipment into AC power, allowing seamless integration with the existing micro grid. Inverters use power electronic components and control algorithms to transform the DC input into high-quality AC output [4]. By ensuring synchronization between the frequency and voltage of the Pico grid and the micro grid, grid-tie inverters enable smooth power transfer, allowing AC power from the Pico grid to be injected into the main grid [2].

To achieve proper synchronization with the micro grid's electrical characteristics, inverters employ phase-locked loops and voltage control mechanisms. MPPT algorithms continuously track and adjust the operating point of solar equipment, optimizing power output and maximizing energy extraction from PV panels. Grid-tie inverters are equipped with anti-islanding measures that detect grid failures or disturbances and disconnect the Pico grid from the micro grid to prevent unsafe operation in isolation [4]. The selection of grid-tie inverters depends on factors like system capacity, voltage requirements, grid regulations, and specific project needs. Table 1 shows the difference of different inverter topologies for selecting a suitable inverter for a specific design. By incorporating grid-tie inverters, Pico grids can seamlessly integrate with AC micro grids, allowing surplus energy injection into the grid and contributing to grid stability, renewable energy utilization, and optimized energy management.

Table 1: Grid-tie inverter topologies

Comparative index	**Small scale**	**Medium scale**	**Large scale**
Power range	<350 W	<10 kW	<850 kW
Configuration	AC module	string	Central
Power Semiconductor device	MOSFET	MOFSET, IGBT	IGBT
efficiency	Lowest	High	Highest
Pros	Flexible, Highest MPPT efficiency	Good MPPT efficiency, Reduced dc wiring	Simple structure, Highest inverter efficiency
Cons	Higher Losses, Higher cost per watt	High component count	Needs blocking diodes, not flexible

4. PROJECT OVERVIEW

An overview of the proposed interfacing system is shown in figure 1 below. The system is required to extract excess energy from the pico-grid (Low DC voltage) and convert to a higher energy AC micro grid. As shown in figure 1 the system is made up of a pico-grid, DC-DC converter, DC-AC inverter, maximum power point tracking (MPPT) control and the grid control unit [8]. The pico-grid generates DC power with the use of PV arrays, which is used to supply a single household. The excess energy from the pico-grid is converted to a voltage suitable for the grid-tie inverter with the use of a DC-DC converter. The DC voltage is further converted to AC using the DC-AC grid-tie inverter. The output of the grid-tie inverter is connected to a LC filter, which smoothens the transients generated, by the IGBT or MOSFET switching in the inverter [10]. The output of the filter can be fed to the utility grid (single or three-phase). The grid control is used to ensure that the requirements of the utility grid are met. The efficient power harvesting is monitored by using MPPT control, which continuously tracks down the energy variations and extract the maximum available power from the micro grid.

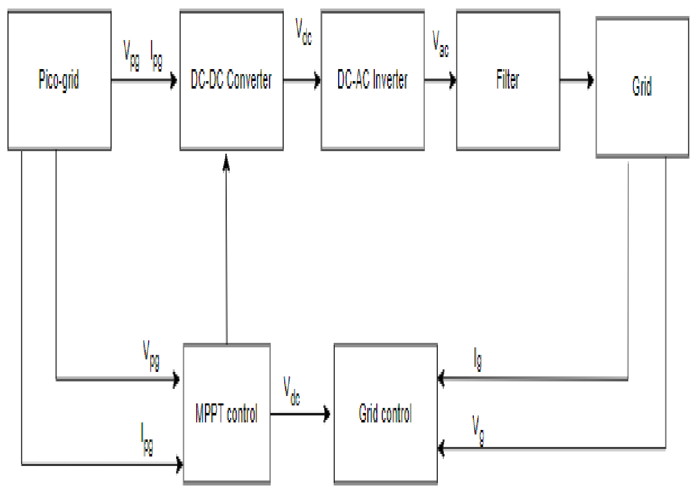

Figure 1: Block diagram of interfacing pico-grid to micro-grid system.

5. METHODOLOGY

5.1 Project initiation and planning

In order for the project to be conducted successfully, both partners should contribute maximum effort and a proper project plan should be set before the project can begin. A meeting was held between the partners to officially begin the project. Since the topic is new to both partners, a lot of research is conducted in order to understand the problem and come up with the best method to provide a solution. Formal meeting will be held with the supervisor to provide the progress made during the course of the project and for guidance.

Every project has uncertainty and a potential to be affected by unforeseen circumstances. This causes risks to arise which may affect the the duration of the project and its outcome. A risk register, which is shown in appendix A, states the risk, which can potentially arise during the course of the project and mitigation strategies for each potential risk. One of the notable mitigations is how the project can be broken down and organized such that tasks are scheduled properly and executed on time to avoid any delays. When the tasks are organized, it makes it easier to identify any potential risks and their mitigation strategies.

A work breakdown structure was constructed to organize the tasks required for the project. This is then used to create the Gantt chart as shown in appendix B. The Gantt chart schedules the tasks by assigning duration for each activity in order to meet the project deadline.

One of the project objectives is to come up with the most cost effective solution. The cost of the project is vital since it contributes to the feasibility of the project. The cost of this project is R0 since all the equipment required for the system is already available at the Actom-lab in the University of Witwatersrand. All the resources required in order to start the execution of the project are listed in table 1 below.

Table 2: Project components

Component	Purpose
Solar panels(Pico-grid)	Generate power from sunlight
Lithium Battery(Pico-grid)	Energy storage
Sensors(MPPT)	Measure relevant parameters of the PV array i.e. PV voltage, PV current and temperature
Microcontroller(MPPT)	Acts as a brain of the MPPT control system
Capacitor(DC-DC converter)	Reduce voltage ripple and provide stable DC output
Transistors (DC-DC converter/ DC-AC inverter)	Used for switching
Diodes (DC-DC converter)	Used as rectifiers to ensure that current flows in one direction.
Output filter	Smooths the AC waveform

5.2 Project execution

For the results of the investigation to be consistent testing should be done at different climate conditions to assess the performance of the pico-grid at different weather conditions and to assess the efficiency of the MPPT at different pico-grid output voltages. The tests for the other parts of the system should be conducted in an indoor environment preferably a lab setting at room temperature.

Stage 1: Project initiation phase

- Defining project scope, objectives, and deliverables

Stage 2: Project Assessment

- Evaluate the existing pico-grid infrastructure and power generation capacity
- Analyse the power demand and consumption patterns.
- Assess technical requirements for interconnection and integration
- Determine the regulatory and legal framework for power exchange

Stage 3: Design Phase

- Identify the connection point between the pico-grid and micro-grid
- Design the interconnection system, considering the power electronics tools required such as the DC-DC inverter, DC-

AC grid-tie inverter and the control circuits.
- Develop technical specification for the required equipment.

Stage 4: Simulation and laboratory tests

- Develop a simulation model of the system
- Run tests in the laboratory to monitor and evaluate the performance of the integrated system.
- Measure Power flows and system reliability
- Analyse economic and environmental impacts.

Stage 5: Critical analysis

- Analyse simulation results and data collected
- Evaluate project feasibility, economic viability, and safety aspects
- Make adjustments or modifications based on findings.

Stage 6: Power exchange phase

- Define the terms and conditions of power supply or sale between the grids
- Determine pricing mechanisms and billing procedure

Stage 7: Project conclusion

- Document the project outcomes, lessons learned and best practices
- Prepare final report summarizing the integration process.

6. CONCLUSION

The project plan has been constructed which is an important step in ensuring that the project is successful. Each project member is aware of the individual effort that should be put in, in order to ensure successful completion of the project. The entire tasked are scheduled properly and within the deadline. The potential risks have been identified and the corresponding mitigation procedures. The project will cost R0 since all the equipment required to construct the system are available at the laboratory.

7. REFERENCES

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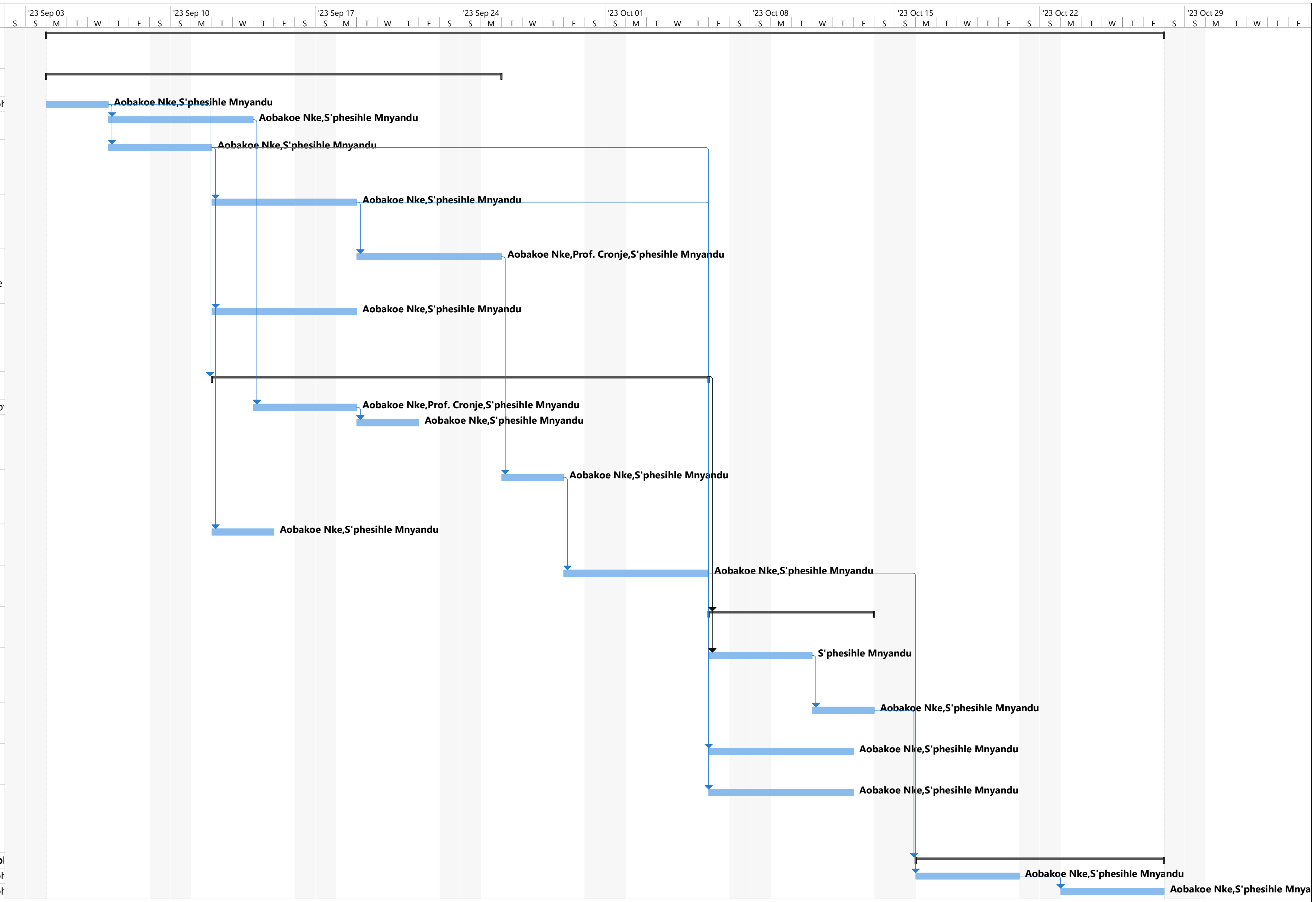
APPENDIX A

RISK REGISTER						Date			
Risk	**Causes (due to …)**	**Probability**	**Impact**	**Risk Rating**	**Response**	**Actions**	**Start**	**End**	**Responsible**
Not finishing the project on time	Not following a proper work schedule and procastinating	LOW	HIGH	MEDIAN	Mitigate	Create a work schedule and follow it	ASAP	End of project	Aobakwe Nke and S'phesihle Mnyandu
Project scope creep	Trying to modufy the project and not comunicating the changes effectively	MEDIAN	LOW	LOW	Mitigate	Only make modifications if the supervisor agrees or suggests it and if time permits	During implem	Testing phase	Aobakwe Nke and S'phesihle Mnyandu
Safety of individuals and equipment during the project	Lab material and electronic devices might be damaged if connected improperly or liquid spillages	HIGH	HIGH	HIGH	Mitigate	Ensure everything is calibrated and connected properly before running lab tests	ASAP	End of project	Aobakwe Nke and S'phesihle Mnyandu
Scheduling shortfalls	The lack of proper schedule with clear start and end dates	HIGH	HIGH	HIGH	Mitigate	Develop a project Gantt chart	Start of project	End of project	Aobakwe Nke and S'phesihle Mnyandu
Design errors	Miscalculation of circuit parameters	LOW	LOW	LOW	Mitigate	Consult with the supervisor on a weekly basis	Start of project	End of project	Aobakwe Nke and S'phesihle Mnyandu

APPENDIX B

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1			**Interfacing a Picogrid to a Microgrid**	**40 days**	**Mon 23/09/04**	**Fri 23/10/27**		
2			**Project Management**	**16 days**	**Mon 23/09/04**	**Mon 23/09/25**		**Aobakoe Nke,Prof.**
3			Project Planning	3 days	Mon 23/09/0	Wed 23/09/0		Aobakoe Nke,S'ph
4			Define technical requirements	5 days	Thu 23/09/07	Wed 23/09/13	3	Aobakoe Nke,S'phesihle
5			Analyze voltage and frequency synchronization methods	3 days	Thu 23/09/07	Mon 23/09/11	3	Aobakoe Nke,S'phesihle Mnyandu
6			Develop control strategies for bidirectional power flow	5 days	Tue 23/09/12	Mon 23/09/18	5	Aobakoe Nke,S'phesihle Mnyandu
7			Implement protection mechanisms for grid stability	5 days	Tue 23/09/19	Mon 23/09/25	6	Aobakoe Nke,Prof. Cronje,S'phesihle Mnyandu
8			Evaluate the economic and environmental impact of integration	5 days	Tue 23/09/12	Mon 23/09/18	5	Aobakoe Nke,S'phesihle Mnyandu
9			**Solar Equipment in Picogrid**	**18 days**	**Tue 23/09/12**	**Thu 23/10/05**	**3**	**Aobakoe Nke,Prof.**
10			Assess solar pan	3 days	Thu 23/09/14	Mon 23/09/1	4	Aobakoe Nke,Pro
11			Determine optimal capacity and configuration of	3 days	Tue 23/09/19	Thu 23/09/21	10	Aobakoe Nke,S'phesihle Mnyandu
12			Analyze efficiency and performance characteristics	3 days	Tue 23/09/26	Thu 23/09/28	7	Aobakoe Nke,S'phesihle Mnyandu
13			Explore mounting and considerations	3 days	Tue 23/09/12	Thu 23/09/14	5	Aobakoe Nke,S'phesihle Mnyandu
14			Evaluate balance of the sytem	5 days	Fri 23/09/29	Thu 23/10/05	12	Aobakoe Nke,S'phesihle Mnyandu
15			**Grid-tie Inverters and control systems**	**6 days**	**Fri 23/10/06**	**Fri 23/10/13**	**9**	**Aobakoe Nke,S'phesihle Mnyandu**
16			Research different types of grid-tie inverters and	3 days	Fri 23/10/06	Tue 23/10/10	9	S'phesihle Mnyandu
17			Investigate control mechanisms for	3 days	Wed 23/10/11	Fri 23/10/13	16	Aobakoe Nke,S'phesihle Mnyandu
18			Monitor the system for inverter	5 days	Fri 23/10/06	Thu 23/10/12	5	Aobakoe Nke,S'phesihle Mnyandu
19			Analyze integration of advance control systems for optimized	5 days	Fri 23/10/06	Thu 23/10/12	6	Aobakoe Nke,S'phesihle Mnyandu
20			**Project Closure**	**10 days**	**Mon 23/10/1**	**Fri 23/10/27**	**17**	**Aobakoe Nke,S'pl**
21			Analyzing results	5 days	Mon 23/10/1	Fri 23/10/20	14	Aobakoe Nke,S'ph
22			Documentation	5 days	Mon 23/10/2	Fri 23/10/27	21	Aobakoe Nke,S'ph

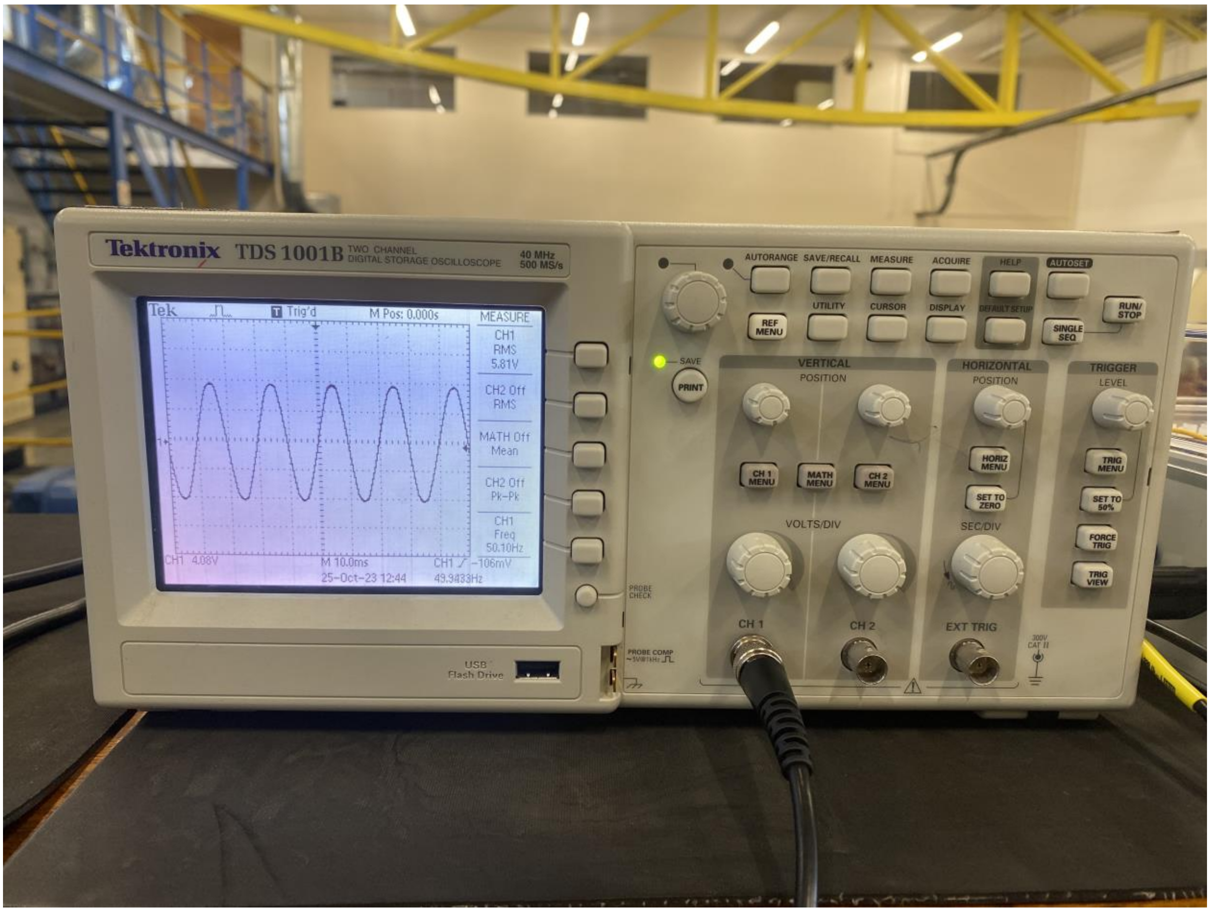


Project: Interfacing a Picogrid t
Date: Sun 23/07/16

Task		Summary		Inactive Milestone		Duration-only		Start-only		External Milestone		Manual Progress
Split		Project Summary		Inactive Summary		Manual Summary Rollup		Finish-only		Deadline	
Milestone		Inactive Task		Manual Task		Manual Summary		External Tasks		Progress	

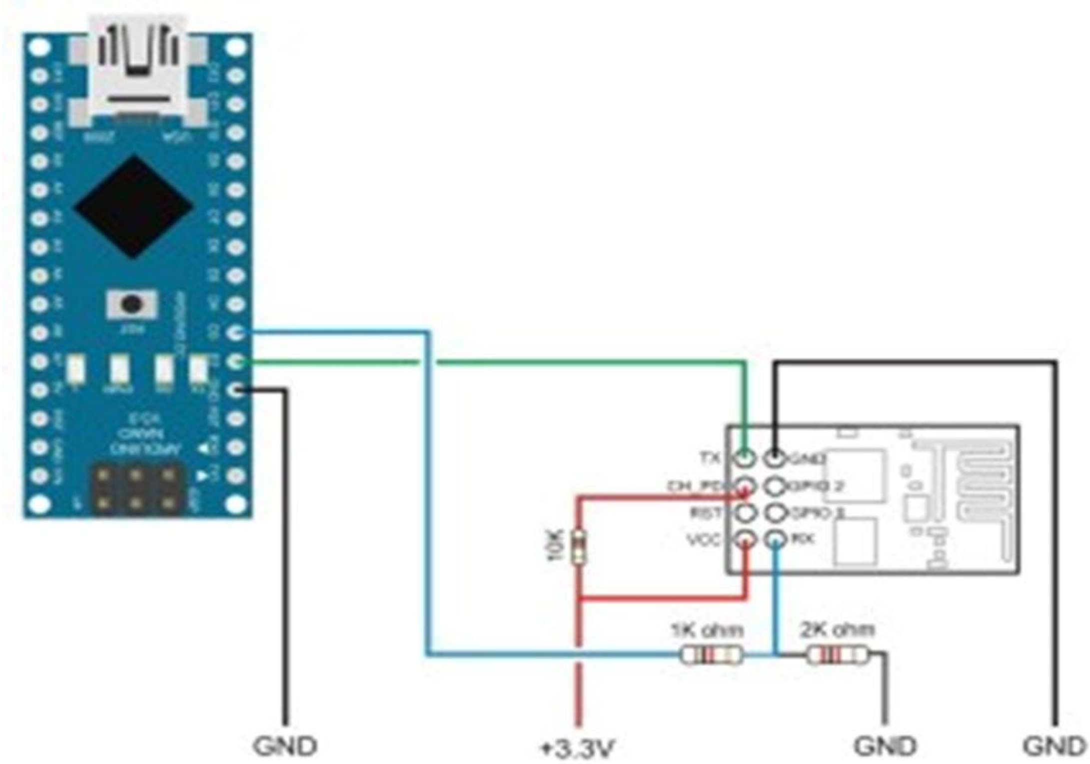
APPENDIX C

The Inverter Output Voltage



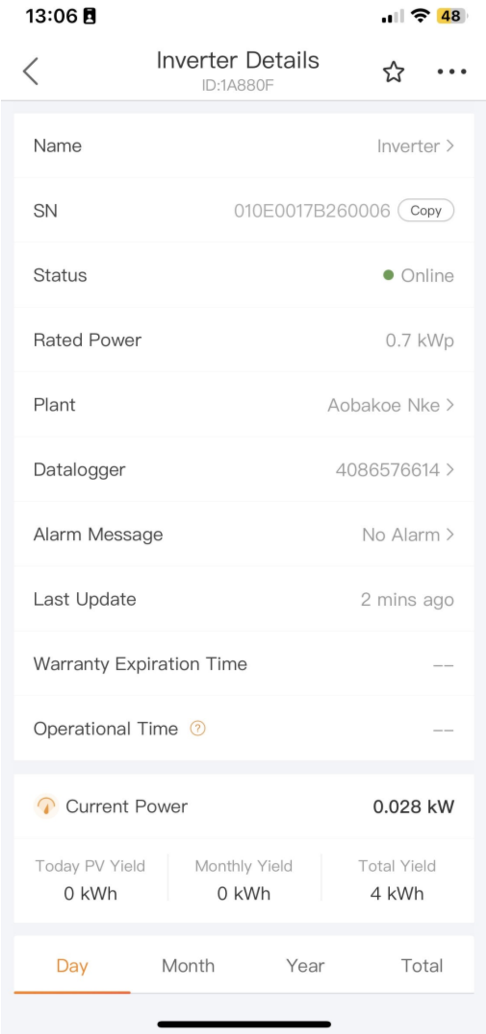
APPENDIX D

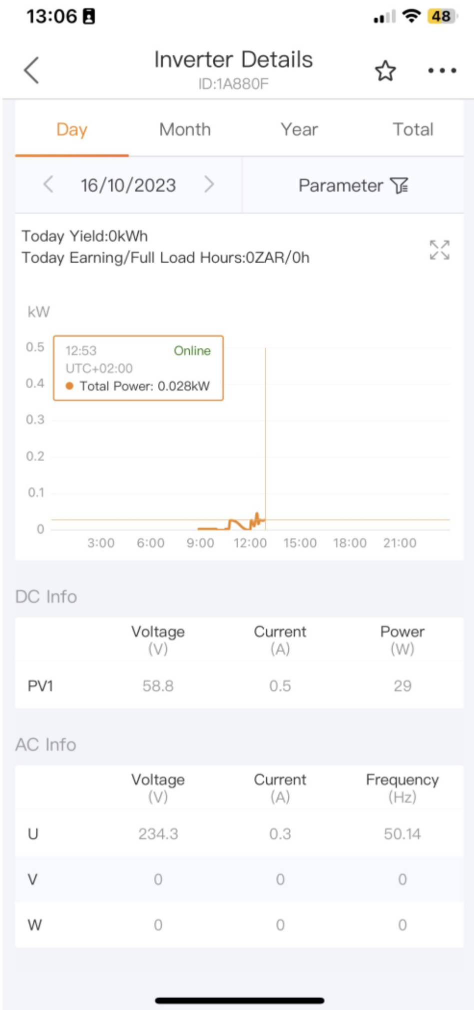
Arduino nano and ESP8266 WIFI Module Setup [6]

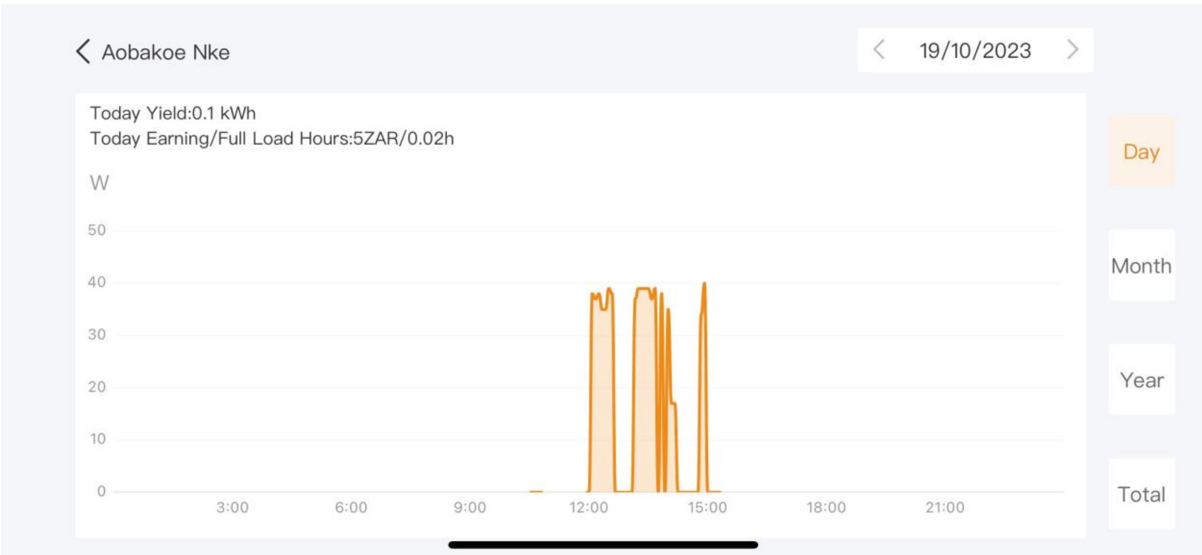


APPENDIX E

Solis Cloud Application







APPENDIX F

Python Code (Control Algorithm)

```python
import requests
import time
from pysolarmanv5.pysolarmanv5 import PySolarmanV5

# Configure the connection parameters
device_ip = "192.168.88.10" #inverter IP address
device_serial_number = 4086576614
device_port = 8899
modbus_slave_id = 1

try:
    modbus = PySolarmanV5(device_ip, device_serial_number, port=device_port, mb_slave_id=modbus_slave_id, verbose=0)
    print("Inverter connected.")
except Exception as e:
    print("Failed to connect to the inverter:", str(e))
    # You can choose to exit the script or handle the failure accordingly

esp8266_ip = "192.168.88.16"  # Replace with your ESP8266's IP address
url = f"http://{esp8266_ip}/"
grid_ON = 0xBE
grid_OFF = 0xDE


power_limit_enabled = 0xAA
```

```python
power_limit_enabled = 0xAA
power_limit_disabled = 0x55


while True:
    response = requests.get(url)

    if response.status_code == 200:
        data = response.json()
        voltage = data.get("voltage")
        print("Voltage reading from ESP8266:", voltage, "V")

        if voltage >= 13:
            print("Excess power is available")
            modbus.write_holding_register(register_addr=3006, value=grid_ON)
            time.sleep(20)
            Solis_DCP = modbus.read_input_register_formatted(register_addr=3006, quantity=2)
            Solis_ACP = modbus.read_input_register_formatted(register_addr=3004, quantity=2)

            # Enable power limit switch
            modbus.write_holding_register(register_addr=3069, value=power_limit_enabled)
            print("Power limit switch enabled.")
            print("{:<23s}{:10.0f} W".format("DC Watts", Solis_DCP))
            Power_limit = ((Solis_DCP/800)*10000)
```

```python
            Power_limit = ((Solis_DCP/800)*10000)
            Power_limit_integer = int(Power_limit)
            try:
    # Attempt to write the value to the Modbus register
                modbus.write_holding_register(register_addr=3051, value=Power_limit_integer)
                print(f"Successfully wrote {Power_limit} to register 3051.")
                time.sleep(10)
                print("{:<23s}{:10.0f} W".format("DC Watts", Solis_DCP))
                print("{:<23s}{:10.0f} W".format("AC Watts", Solis_ACP))
            except Exception as e:
                print(f"Failed to write to register 3051: {str(e)}")

            print("Status- Generating Power.")
        else:
            print("No excess power available")
            modbus.write_holding_register(register_addr=3006, value=grid_OFF)
            print("Status- NO Power.")
    else:
        print("Failed to retrieve data from ESP8266")

    time.sleep(30)  # Add a delay to control the frequency of checks
```

APPENDIX G

Arduino IDE Code to setup the ESP8266 WIFI Board to a local WIFI

```
#include <ESP8266WiFi.h>
#include <ESP8266WebServer.h>

const char* ssid = "EnergyLab";
const char* password = "3n3rgyl@b!";
ESP8266WebServer server(80);

void setup() {
  Serial.begin(115200);
  WiFi.begin(ssid, password);

  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }

  Serial.println("Connected to WiFi");


  Serial.print("IP Address: ");
  Serial.println(WiFi.localIP());  // Print the IP address

  server.on("/", HTTP_GET, handleRoot);
  server.begin();

}


void loop() {
  server.handleClient();  // Handle incoming HTTP requests
}

void handleRoot() {
  // Read the voltage from the analog pin (A0)
  int voltage = analogRead(A0);

  // Convert the analog reading to voltage (assuming a 10-bit ADC)
  float voltageValue = (voltage / 1023.0) * (3.3*4.4) + 0.7 ;  // Assuming a 3.3V reference voltage
  Serial.println(voltageValue,3);

  // Create a JSON response with the voltage reading
  String response = "{\"voltage\": " + String(voltageValue, 2) + "}";

  // Set the Content-Type header to indicate JSON data
  server.sendHeader("Content-Type", "application/json");
  server.send(200, "application/json", response); // Send the JSON response
}
```

WEEK 1 Meeting Cohort 8

Groups: 23G47, 23G01, 23G18, 23G22, 23G09.

Supervisors: Professor Willie Cronje , Doctor Lesedi Masisi.

Minutes of the Meeting

Meeting 1 (Monday 11/09/2023)

Minutes provided by 23G18.

Chaired by 23G18.

Location and Time: Online

Agenda: Introduction. Overview of Projects. What has been done? What we plan to do? Format for how meetings should be run. What kind of feedback can we expect from supervisors?

Attendees: 23G47, 23G01, 23G18, 23G22, 23G09, Dr Lesedi Masisi, Prof Willie Cronje.

Student Presentations

23G18

Title: Interfacing Pico-grid to a Micro-grid

Progress: Started assembling the laboratory prototype of the system

Future: Order boost converter which is the missing part of the laboratory prototype

23G47

Title: Bi-directional energy meter for DC grids

Progress: Working on researching the sensors to be used for the project. Evaluating which method is suitable for the system i.e flyback converter method and voltage divider method.

Challenges: Working on the language to be used to program the Arduinos.

23G01

Title: LED control for mosquito colony breeding

Progress: Working with the semens logo and the deemer.

Challenges: Trying to get the right PWM waveform to control the deemer. Trying to understand the relationship between the input voltage and the output of the Deemer.

Future: Trying to generate the PWM signal which controls the output of the Deemer.

23G22

Title: Analysis of a hybrid energy storage system for vehicles

Progress: Successfully gathered the data for the emulator such as the voltage and current characteristics. Successfully compiled the costs of the project components.

Challenges: Current sensors used are not giving the expected output.

Future: Submit component list. Construct the starter motor emulator.

23G09

Title: Vehicle to house energy supply

Progress: Estimated the load profile for households, with peak demand power of 1.5 kW. Inverter simulation using matlab simulink. Boost converter simulations.

Future: Simulation of inverter parasitic effects. Design inverter PCB. PWM coding.Build inverter. Implement a BMS strategy.

Plans for following meetings and General comments:

Dr Lesedi Masisi- Dr Lesedi Masisi- One slide presenting the challenges you are facing.

Prof Willie Cronje- Meetings should be about presenting the challenges instead of doing presentations on your progress. Focus mainly on the challenges .

Next Meeting: To be held in the Genmin Lab on the 15th of September at 10h30. The meeting will be chaired by group 23G01.

ELEN4002A – Investigation Project

Minutes Of Meeting: Cohort Meeting #2

Cohort Group 8

15/09/2023

Meeting Purpose: Second Weekly Meeting of Cohort Group 8

Meeting Scheduled: 15/09/2023 : 10:30 am

Meeting Start: 15/09/2023 : 10:32 am

Venue: Online, via Microsoft Teams. Web link was delivered to all participants via email

Attendees Present: Professor W. Cronje. All members of groups 23G01, 23G09, 23G18, 23G22, 23G47

Attendees Absent: Professor L. Masisi

Meeting Chair: Daniel Taim (23G01)

Meeting Secretary: Michael Landgrebe (23G01)

Agenda:

10:32 – Meeting opening by Chair, stated format of each group presenting the week's progress, challenges, and areas of focus for the following week.

10:33 – Group 1 (23G01) summarises topic of developing an LED dimming control system for malaria research. Notes issues encountered with behaviour of dimming unit when connected to control unit. Outlined plan for resolving issue, but noted uncertainty as to the cause of unexpected behaviour in the integrated system. Resolved to further study the cause of the issue.

10:39 – Group 9 (23G09) noted work on an inverter and PI controller. Reported that simulation yielded expected results. Physical system testing proposed would use a 100V battery. Professor Cronje commented that obtaining a 100V battery would prove difficult. Group resolved to design the PCB, and analyse the PWM signal over the next week.

10:43 – Group 18 (23G18) introduced topic of pico-grid and micro-grid operation. Work over the last week included investigation of the normal operation of an inverter, whereby synchronisation with the inverter was achieved. Issues with communicating with the inverter were noted. The group stated a need to mimic a varying load, and equipment is required to do so.

10:49 – Group 22 (23G22) detailed issues obtaining components, stemming from supplier delays. Professor Cronje suggested accelerating the matter, and following up with the supplier.

10:52 – Group 47 (23G47) introduced the topic of the DC bidirectional meter. Noted voltage readings successfully being displayed. A need to measure current was reported, and the group has ordered a current sensor. Relevant computations performed.

10:55 – Meeting conclusion. Discussion of administrative issues regarding minutes of meetings.

10:56 – Boitumelo Sibi of Group 9 (23G09) offers to chair the next meeting on 22/09/2023. Meeting ends.

Time of meeting end: 10:56 am

Date and time of next meeting: 22/09/2023 : 10:30 am

ELEN4002A Energy and Power Investigation lab Projects

Date | Time 22/09/2023 10:30 AM | Location Microsoft Teams

Meeting called by	EIE Investigation course coordinator
Program	Energy and Power
Meeting type	Cohort 8 Meeting 3
Facilitator	Boitumelo Sibi
Note taker	Cebolenkosi Zulu
Time keeper	Cebolenkosi Zulu

Attendees:

Supervisors Prof W. Cronje and Dr L. Masisi

Students Boitumelo Sibi, Cebolenkosi Zulu, S'phesihle Mnyandu, Aobakoe Nke, Success Maake, Molaetsa Mphahlele, Thabang Banyini, Jabulani Skosana, Michael Landgrebe, Daniel Taim.

Agenda

The aim of this meeting is to report back on the 3rd week of the lab investigation project. Project groups are expected to report on the progress and challenges encountered during the week. The time allocated for each group is 10 min. Supervisors are expected to give feedback and/or reply at the end of the meeting to students in a one-to-one session. The date and leadership of the next meeting will be discussed.

Minutes

Start time: 10:30
Welcoming remarks by Boitumelo Sibi
10:32- Group 9 Discussed challenges in coding PWM for MOSFET control. Discussed the need to print the PCB for the single-phase inverter.

10:35- Group 18 Elaborated on their project involving interfacing a photovoltaic grid-tie inverter remotely using Python to read parameters remotely to successfully communicate over Modbus. Questions were raised by Michael Landgrebe regarding hardware used for communication.

10:39- Group 22 Started the mechanical part of the project, their critical ordered parts will arrive next week Tuesday. Discussed the issue of non-constant battery voltage. Considering using the boost converter to achieve constant voltage delivery. Raised a question regarding the output of the boost converter, voltage relationship to the applied input voltage.

10:44- Group 7 Discussed their progress in measuring current and voltage in their system. Changed the display to have different results. Explained the failure of their system current sensor, and ordering of a new sensor.

10:47- Group 1 Presented the analysis of control signal voltage and the need for a light sensor. Discussed using the MOD bus protocol and a Raspberry Pi for integration. Outlined their plans for further testing and integration of their system.

10:51- Conclusion The next meeting will be chaired by Group 22 on September 29 at 10:30. Supervisors expressed interest in meeting with specific groups after the meeting. Some technical difficulties were noted during the meeting.

End time: 10:55

Key points

1. All group members were present and summarized work done, and laid out a plan for the week ahead.
2. Group 22 will chair the next meeting.
3. The meeting chairperson (Boitumelo Sibi) had issues with connectivity and this had an impact on the smooth running of the meeting.
4. Prof W. Cronje noted that online meetings are not all reliable as sometimes the technology fails us.

Details of next meeting

Meeting date:	29 September 2023
Meeting time:	10:30 AM
Meeting location:	TBA
Meeting facilitator:	Group 22
Minutes issued by:	Group 22

WEEK 4 COHORT 08 MEETING MINUTES

The fourth Cohort meeting of the investigation project was chaired by group 22. The group chaired and documented the meeting minutes. The meeting was held on Microsoft Teams on the 29th of September 2023 at 10:30. The meeting was chaired by Jabulani Skosana, and the meeting minutes were taken by Thabang Banyini.

Opening Remarks:

The purpose of the meeting was for all the groups within the cohort to share their progress and to address any questions and challenges they are facing with supervisors.

Attendees:

Supervisors: Prof Willie Cronje and Dr. Lesedi Masisi

Groups: Group 22 (both students), Group 47 (both students), Group 18 (only one student), Group 9 (both students), Group 18 (both students).

Apologies:

One student from Group 18 apologized for their absence. The group member is S'phesihle Mnyandu.

Meeting Agenda:

- Each group was allocated time to present their progress, share challenges they have encountered, and outline their next milestones.
- General Discussion and Q&A sessions followed each group's presentation.

Group 22: Analysis of hybrid energy storage system for vehicles

The group received components on Tuesday morning and started connecting their prototype's electrical side. They were able to finish connecting the measurement and control circuitry which is used to control the programmable load. The problem they are facing is that the LCD display was not responding during the testing. They intend to debug the circuit and fix the problem. They also started connecting the programmable load circuit part of their project and it was stated that they intend to finish with the circuit on Friday after this meeting.

Questions: No questions were recorded from either the supervisor or students.

Group 47: Bi-directional energy meter for DC grids

The group stated that they got a new sensor for their meter because the one they were using burnt down and they managed to measure voltage and current. They also successfully set up the meter and it works. The group is now working on improving the efficiency of the meter as it is a requirement to do so. The group also managed to use two sources which model house A and house B. The meter is now able to read the energy, but the problem is it takes a bit of time because the power consumption is too low.

Questions: No questions were recorded from either the supervisor or students.

<u>Group 18: Interfacing a Picogrid to Microgrid</u>

The group stated that the objective for the week was to figure out the Python Code to control the inverter Remotely. The group had struggled with the code since the previous week, but they finally cracked it and got it working. The issue they are facing is that they are still waiting for a WIFI module to control the Arduino to be able to control the power supply.

Questions: No questions were recorded from either the supervisor or students.

<u>Group 8: Vehicle to house energy supply</u>

The group stated that they have been struggling with generating PWM signals for the MOSFETs in the H-bridge. They found out that the problem was that the Arduino Uno could not generate four PWM signals. After consultations with their supervisor Dr. Masisi, they decided to use the bipolar SPWM modulation technique to generate PWM signals. They stated that after the meeting and in the upcoming week they will be testing the circuit and modelling the battery of the electric vehicle along with the battery management system.

Questions: No questions were recorded from either the supervisor or students.

<u>Group 1: LED light control for mosquito colony breeding</u>

The group stated that this week and the previous week the aim was to interface the Raspberry Pie to connect to the Siemens logo. The group was able to get it working through a Modbus communication and they are now able to measure the light intensity to the input voltage they are supplying to the system. They also stated that the aim for this week was to measure more of the light intensity so that they could generate the lighting curves for their system.

Questions directed to Prof Cronje: "Would you like us to work with the prototype board you have provided, or we can continue to work with the strip lights?"

Reply From Prof Cronje: "Use what is convenient at the moment because time is sufficient".

Adjournment:

The meeting adjourned at 10:45 a.m. The next meeting will take place on the 6th of October 2023 at 10:30 a.m. and will be held on Microsoft Teams. The meeting is to be chaired by Group 47.

ELEN4002A – Investigation Project Minutes Of Meeting

Meeting #5

Cohort 8

06 October 2023

Meeting Purpose: Fifth Weekly Meeting of Cohort Group 8

Meeting Scheduled: 06 October 2023

Meeting Starting time: 10:30 am

Venue: Online, via Microsoft Teams. Web link was delivered to all participants via email

Attendees Present: Professor W. Cronje. All members of groups 23G47, 23G01, 23G09, 23G18, and 23G22.

Attendees Absent: Dr L. Masisi.

Meeting Chair: Success Maake (23G47)

Meeting Secretary: Molaetsa Mphahlele (23G47).

Agenda:

1. Week 5 progress report including barriers encountered.
2. Milestones hoping to be achieved for week 6.
3. Question and answer session.

Presentations:

Group 47- Topic: Bi-directional energy meter for DC grids.

Maake Success did the presentation for the group.

- We were able to successfully add overvoltage protection circuitries for our meter, this includes an overvoltage protection circuit for the supply of our meter and an overvoltage protection circuit for our microprocessor which is the Arduino and also we were able to add a filtering circuit for our voltage measurement system.
- The problem we encountered is the accuracy of our current measurement system as it keeps on changing, we therefore had a conversation with Prof Cronje who explained that our sensor might be getting interference (magnetic interference) from various source in the lab as well as some components of our circuitry, he then suggested that we build an isolation system that will prevent/limit the interferences.
- The next milestone is to research and build such a system that will help us encounter this problem.

Questions or comments for group 47: None were raised/made from the other groups and Professor W. Cronje

Group 18- Topic: Interfacing a Picogrid to a Microgrid.

S'phesihle Mnyandu did the presentation for the group.

- This week we have been trying to get the Arduino to communicate with the WIFI module for the circuit that will be responsible to monitor the voltage levels remotely.
- The problem we encountered is that we have been struggling to get the Arduino to communicate with the WIFI module, however we had a consultation with 'Skhumbuzo' from the electronics lab and we determined that the issue is that the WIFI module is still running the initial code we uploaded while we were still testing.
- The next milestone is for us to restore the original firmware to be able to communicate using the Arduino to send commands to the ESP/WIFI module.

Questions or comments for group 18: None were raised/made from the other groups and Professor W. Cronje.

Group 9- Topic: Vehicle to house energy supply.

Boitumelo Sibi did the presentation for the group.

- This week we were able to get the inverter to function as desired, this was achieved after we successfully tested it with a 12V and 30V DC power supply.
- The problem we encountered was with the driver we purchased as it was not giving out the signal on the high output side to drive the high side MOSFET, the issue was that it was only giving a PWM on the low output side. We countered this issue by reviewing the data sheet and making proper connections as recommended by the manufacturer.
- We are currently struggling with the design of the low pass filter that will filter out the high frequencies on the output inverter.
- The next milestone for us to complete the BMS simulation and test the boost converter, we will also print out the final PCB for both the inverter and boost converter.

Questions or comments for group 9: None were raised/made from the other groups and Professor W. Cronje.

Group 1- Topic: LED Light control for mosquito colony breeding.

Daniel Taim did the presentation for the group.

- This week we successfully measured how the voltage that we are putting in compares to the light intensity we are getting out, and we got a piece wise linear function that is determined by the dimmer that we are using which relates the voltage in compared to the brightness out.
- We were able to invert it and test it with different amounts of lights and LED's and when we input the brightness in from our software, the brightness that we are getting out is very close when using the R-squared coefficient (linear regression coefficient) of about 99.85.
- We also created a good setup to test our brightness using a Blackbox.
- The next milestone for us to deal with the non-linearities.

Questions or comments for group 1: None were raised/made from the other groups and Professor

W. Cronje.

Group 22- Topic: Analysis of a hybrid energy storage system for vehicles

Jabulani Skhosana did the presentation for the group.

- This week we managed to interface the load circuit. When conducting some tests, we encountered issues from the MOSFET's as they were burning, and upon a thorough review we determined the issue to be short circuiting the components and also there were defects from the MOSFET's.
- The next milestone for us to deal with this issue and also replace the burned MOSFETS.

Questions or comments for group 22: None were raised/made from the other groups and Professor W. Cronje.

Clossing remarks: The chair of the meeting suggested to hold the next meeting which will be held on the 13th of October 2023 physically to see the actual progress made by the groups and also in preparation of open day which will be held on the 19th of October 2023. The venue for the meeting will be the Genmin laboratory and the meeting will be chaired by Daniel Taim.

Minutes Submitted by: Group 47 (Molaetsa Mphahlele and Maake Success).

ELEN4002A – Investigation Project

Minutes Of Meeting: Cohort Meeting #6

Cohort Group 8

13/10/2023

Meeting Purpose: Sixth Weekly Meeting of Cohort Group 8

Meeting Scheduled: 13/10/2023 : 10:30 am

Meeting Start: 13/10/2023 : 10:37 am

Venue: Genmin Laboratory

Attendees Present: Dr. L. Masisi. All members of groups 23G01, 23G09, 23G18, 23G22, 23G47

Attendees Absent: Professor W. Cronje

Meeting Chair: Daniel Taim (23G01)

Meeting Secretary: Michael Landgrebe (23G01)

Agenda:

10:37 – Meeting Start, received email from Professor L. Masisi requesting the meeting be rescheduled for 11:45. All parties present agreed to the rescheduled time

10:40 – Meeting Adjourned

11:48 – Meeting Resumed. Dr. Masisi, and all groups present.

11:49 – Group 1 Presenting

- Reported project in final stages, all major experimental tests required have been performed, and a functioning model is ready for presenting at Open Day
- Detailed the development of the equivalent circuit model has also reached conclusion
- Showed results indicating that set point versus measured brightness achieves good correlation, indicating system success
- Dr. Masisi inquired about the methodology for measuring LED brightness. Group 1 discussed the apparatus of the lux-meter and a box spray painted black to avoid the effect of reflections, in addition to the methodology for performing measurements

11:54 – Group 9 Presenting

- Group 9 demonstrated test and model apparatus
- Noted an issue with incorrect voltage measurements at output, solved issue with filter. Measurements across filter capacitor are now correct
- Dr. Masisi questioned the group on the modulation index of 0.9 used. Recommended an investigation on where the linear region and saturation occur, and how it affects modulation
- Group 9 reported issue with the toroid used
- Dr. Masisi recommended acquiring a commercial boost converter rather than a self-designed one

12:05 – Group 18 Presenting

- Demonstrated an inverter system for taking excess power from thje system and powering a micro grid
- Noted wifi modbus integration with inverter was successful, noted that a remote monitoring application is available
- Group discussed that the voltage monitoring circuit is functional – working with an analog sensor
- Dr. Masisi questioned the automation implementation with the Python script. The group responded that voltage is sampled every one second
- Dr. Masisi noted the need for being able to concisely explain the project, and noted the need to check graduate attributes needed for factors such as a model element
- Group 18 noted challenges were faced in getting the Arduino wifi module communicating with the inverter

12:14 – Group 22 Presenting

- Group demonstrated the equipment of the starter motor emulator project. Demonstrated the separate measurement and load circuitry
- Dr. Masisi noted the need to be certain of important parameter values when questioned
- Group noted that initial testing with batteries damaged components, and a system migration has been made by switching to testing using a power supply
- Dr. Masisi noted that current supplied by the power supply is insufficient
- Group noted that the next test will be performed with a battery, and that the system will need to interface with a battery. Noted an issue with short circuits and a concern for component damage on running higher current tests
- Dr. Masisi commented on the need for a more robust setup to avoid short circuits, and the need for circuit protection and insulation

12:24 – Group 47 Presenting

- Group demonstrated the equipment of the bidirectional DC meter. Demonstrated the feature of resetting the meter, with 20A, 60V limits. Noted testing being performed using a 30V, 6A source due to source limitations
- Group further showed two rheostats representing two houses. System works on a net energy basis, determining which house draws more power
- Noted over-voltage protection for the measurement system. If recording system voltage exceeds, a trip occurs, protecting the Arduino and other sensitive equipment. Noted measurement system powered using a 12V buck converter
- Dr. Masisi questioned why protection circuitry was focused on the meter instead of the loads
- Group noted that a house overcurrent protection system is in development
- Group discussed that system facilitates use of a battery in one house, and solar panels in another
- Dr. Masisi noted a need for testing the system with higher currents

12:35 – End of group presentations. Group 1 inquired about open day logistics. Dr. Masisi discussed a need for interaction with visitors, and to use the event to prompt questions from visitors in order to identify key focus areas that should be included or emphasised in the final report

12:40 – Dr. Masisi noted the possibility of another meeting next week

12:40 – Meeting End

Time of meeting end: 12:40 pm