

**REPUBLIC OF RWANDA**  
**ULK POLYTECHNIC INSTITUTE**  
**POBOX 2280 KIGALI**  
**WEBSITE: //WWW.ULKPOLYTECHNIC.AC.RW**  
**EMAIL: POLYTECHNIC.INSTITUTE@ULK.AC.RW**  
**DEPARTMENT OF ELECTRICAL AND ELECTRONICS**  
**ENGINEERING**  
**OPTION: ELECTRICAL TECHNOLOGY**

**FINAL YEAR PROJECT: DESIGN AND  
IMPLEMENTATION OF A DC MICROGRID**

**Final year Project Submitted in Partial Fulfilment of  
the Requirement for Award of Advanced Diploma in  
Electrical Technology**

**Prepared by: LUETH ELIJAH MALUK LUETH**  
**Roll number: 202150552**

**Supervisor: Eng. KARANGWA AUGUSTIN**

**Kigali, October 2024**

**DECLARATION A**

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POLYTECHNIC INSTITUTE Supervisor.

Name of Supervisor: Eng. KARANGWA AUGUSTIN

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Date:.....

## **DEDICATION**

I would like to dedicate this work to my mother, my sisters, my grandparents and my friends; they have provided me with unlimited financial and moral support but also presence throughout this career path.

I would also like to express my gratitude to my Head Of Department (HOD) and supervisor, whose guidance and expertise have challenged me to grow and develop as a student.

Finally, I would like to acknowledge my classmates and friends, whose camaraderie and support have made this journey all the more fulfilling.

To my family, supervisor, classmates, and friends thank you for being a part of my academic journey and for helping me to achieve my goals.

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I am also grateful to my brothers for their assistance in procuring materials and tools essential for the project. Their support has been a cornerstone of this work.

## ABSTRACT

This project presents a comprehensive study on DC microgrids, emphasizing their significance, design, and implementation in modern energy systems. As the demand for efficient, reliable, and sustainable energy solutions grows, DC microgrids emerge as a promising alternative to traditional AC grids. This book explores the fundamental concepts and benefits of DC microgrids, including their ability to enhance energy efficiency, integrate renewable energy sources, and improve power quality. The proposal outlines a systematic approach to designing a DC microgrid, incorporating key components such as energy storage systems, power converters, and control strategies. By examining case studies and current advancements in the field, this book provides a detailed framework for the successful deployment and optimization of DC microgrids. The insights offered aim to guide researchers, engineers, and policymakers in advancing the development of resilient and innovative energy infrastructure.

The increasing demand for reliable and sustainable energy solutions has led to significant advancements in microgrid technology. Unlike traditional AC grids, DC microgrids offer several advantages such as reduced conversion losses, improved system stability, and enhanced compatibility with renewable energy sources. This book aims to provide a comprehensive overview of the design, implementation, and management of DC microgrids.

**Keywords:** DC Microgrids, Convertors, reliable, PV, MOSFET

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**LISTS OF ACCRONYMNS AND ABBREVIATIONS**

**DC:** Direct current

**AC:** Alternating current

**MG:** Microgrid

**DG:** Distributed Generation

**PV:** Photovoltaic

**DER:** Distributed Energy Resources

**PEVs:** Plug-in Electric Vehicles

**CHP:** Combined Heat and Power

## **CHAPTER 1: GENERAL INTRODUCTION**

### **1.0 Introduction**

To mitigate the effects of fossil fuels and climate change, it is necessary to consider alternative means for generating electricity. The rising demand for fossil fuels is driving people into renewable sources of energy. The use of solar and wind energy for power has been made viable by recent advances in semiconductor technology. Since most electronic loads need a DC supply, the ac power is converted into DC within the device itself to supply the load. The DC voltage of the solar panel is converted to alternating current and returned to DC prior to charging. PV is a DC power generation system. Due to additional converters reducing the performance of the device tremendous amount of power is wasted. There is a simpler way to directly supply the power from the source. DC micro grid is then applied. More performance and reliability can be accomplished by using this method. When power from solar or wind systems are not sufficient, the micro grid can receive power from the batteries. Also due to power cuts of the conventional grid during extreme common events such as heavy rains, strong winds, deforestation and landslides, a DC microgrid provides a relief from these power cuts since these very extreme events such as heavy winds and heavy rains provides the MG with energy. The proposed DC Microgrid consists of solar PV array, Utility power conversion system, battery bank, power converters for interfacing with the DC bus.

The output of the PV array is connected to the DC grid through the DC-DC boost converter. The power from the wind turbine is rectified to DC and fed into the DC bus through a power converter. MOSFET is used for the switching purpose.

The output from the DC-DC boost converter is connected to the DC micro grid where the loads are connected. The charging and discharging of the battery is done by bidirectional buck-boost converter which also regulates the DC link voltage. This is shown in the figure below.

### **1.1 Background of the study**

Microgrids are localized energy systems that can operate independently or in conjunction with the main power grid. They integrate various distributed energy resources (DERs) such as solar panels, wind turbines, batteries, and combined heat and power (CHP) systems to provide reliable and efficient energy solutions. The concept of microgrids has

gained traction due to the increased demand for sustainable energy sources, resilience against grid failure, and the need for improved energy management.

DC microgrid concept is the same as the conventional microgrid, but power is available in the DC form. It is the integration of energy storage devices and the main grid. DC microgrid can operate in both the ways, grid-connected mode and islanded mode of operation. In isolated DC microgrid operation, two major operational issues, such as standalone DC microgrid system and feasible, adaptable, and realizable and interconnection of two local dc grids, are prevalent.

## **1.2 Statement of the problem**

In 11<sup>th</sup> December 2015, a storm hit insulators at a location called Kilinda, resulting in power outages that lasted for several months. The outages impacted various areas of the local economy, REG had announced it would carry out “urgent” repair works of electrical equipment in a number of substations – Mururu I, Mashyuza, and Birembo – causing hour-long interruptions of power supply between September 15 and 17. Business centres bore high cost of running generators while those in areas earlier notified of the outage complained it took longer periods than stated in the announcement. Other business people in Kigali who run bars, restaurants, hotels and supermarkets counted great losses after electricity went off. Universities also incurred great losses in Generator running costs.

And especially business owners have felt the pinch not only because they rely on electricity to power refrigerators, in which they store perishable products, but also since it is costly to use generators for their power needs.

For this reason, the implementation of DC MGs on different sectors of the economy besides residences has been considered to improve the reliability and to have a backup during electric emerges. A smart microgrid integrating a mix of renewable resources, generators and battery energy storage systems can effectively make electricity more affordable and more reliable, while also reducing the environmental impact of the electricity production in short Microgrids can ensure their owner spends the least amount possible on electricity, while ensuring continuity of supply.

## **1.3 Objectives of the study**

### **1.3.1 Main objectives**

The main objective of a DC Microgrid is to assess the economic feasibility and benefits of implementing a DC microgrid compared to traditional AC systems.

### **1.3.2 Specific objectives**

1. Select appropriate components (e.g., converters, batteries, controllers) for the DC microgrid.
2. Design strategies for integrating renewable energy sources such as solar panels or wind turbines.
3. Develop control strategies for balancing supply and demand.
4. Implement and test energy management algorithms to optimize power distribution and storage.
5. Build a small-scale prototype of the DC microgrid to validate theoretical models and simulations.

### **1.4 Research Questions**

To guide this research and meet its objectives, the following questions have been formulated:

1. What are the primary benefits of implementing DC MGs over the conventional grid systems?

This question aims to explore the advantages that MGs can offer to the different sectors of the economy including residential buildings.

2. How do MGs enhance energy resilience in hospitals during emergencies or power outages?

This question focuses on understanding how MGs can provide critical backup power for health care facilities when conventional grid system fails.

3. What are the economic implications of adopting MG technology in residential buildings, business centers, hospitals, Learning institutions and other sectors of the economy?

This question investigates the financial aspect of transitioning into an MG system.

## **1.5 Scope and limitations**

### **1.5.1 Scope**

#### **1.5.1.1 Definition and Objectives of DC MGs**

The project will begin by defining what a microgrid is, including its components such as distributed energy resources (DERs), energy storage systems, and control systems. The objectives will focus on enhancing energy reliability, sustainability, and efficiency within the selected institutions.

#### **1.5.1.2 Technological components**

The proposal will explore various technologies involved in microgrid implementation such as solar photovoltaic (PV) systems, wind turbines, battery storage technologies, smart meters, and advanced control algorithms. It will also cover integration with existing grid infrastructure.

#### **1.5.1.3 Economic Analysis**

A detailed economic analysis will be included to assess the cost-effectiveness of implementing microgrids in these settings. This may involve life cycle cost assessments, return on investment calculations, and potential funding sources or incentives available for renewable energy projects.

### **1.5.2 Limitations**

#### **1.5.2.1 Technical constraints**

There may be limitations related to the availability of specific technologies or expertise required for designing complex microgrid systems tailored to each institution's needs.

#### **1.5.2.1 Financial limitations**

Budget constraints could limit the extent of research or implementation phases within the project scope; securing funding might pose a challenge depending on institutional priorities or economic conditions

## **1.6 Significance of the Study**

### **1.6.1 Energy saving**

One of the primary significances of DC microgrids is their ability to improve energy efficiency. Traditional AC systems experience losses due to conversion processes when integrating renewable energy sources, which often generate DC power. By utilizing a DC microgrid, these conversion losses can be minimized, leading to more efficient use of

generated energy. This efficiency is crucial in reducing overall energy consumption and lowering operational costs.

### **1.6.2 Integration of renewable energy resources**

The transition towards sustainable energy solutions is a global priority. DC microgrids facilitate the integration of various renewable energy sources, such as solar photovoltaic (PV) systems and wind turbines. These technologies produce electricity in DC form, making it easier to connect them directly to a DC microgrid without the need for inverters that convert DC to AC. This direct integration not only enhances system performance but also supports the broader goal of reducing greenhouse gas emissions.

### **1.6.3 Reliability and Resilience**

DC microgrids enhance the reliability and resilience of power supply systems. In scenarios where the main grid experiences outages or disruptions, a well-designed DC microgrid can continue to operate autonomously, providing essential services to critical loads such as hospitals or emergency response facilities. This capability is increasingly important as climate change leads to more frequent extreme weather events that threaten traditional power infrastructure.

### **1.6.4 Cost-Effectiveness**

The implementation of DC microgrids can lead to significant cost savings over time. By reducing transmission losses and minimizing reliance on expensive peak power generation from fossil fuels, these systems can lower electricity bills for consumers. Additionally, they provide opportunities for demand-side management strategies that optimize energy usage patterns based on real-time data analytics.

### **1.6.5 Support for PEVs**

As electrification trends continue globally—particularly in transportation with electric vehicles (EVs)—the demand for efficient charging infrastructure grows. DC microgrids can support fast-charging stations by providing high-power direct current directly from renewable sources or local storage units, thus facilitating the transition towards electric mobility.

## **1.8 Organization of the study**

This study is structured into five chapters, each dedicated to specific aspects of the research:



- Chapter 1 introduces the topic and outlines the objectives.
- Chapter 2 reviews relevant literature on microgrid technology.
- Chapter 3 discusses methodology.
- Chapter 4 presents findings from case studies.
- Chapter 5 concludes with recommendations for future research.

## **CHAPTER 2: OVERVIEW OF DC MICROGRIDS**

### **2.1 Introduction to DC Microgrids**

DC microgrids are localized energy systems that can operate independently or in conjunction with the main power grid. They utilize direct current (DC) for electricity distribution, which is particularly advantageous for integrating renewable energy sources such as solar panels and wind turbines. The increasing penetration of distributed generation and the need for efficient energy management have led to a growing interest in DC microgrid technology.

### **2.2 Components of DC Microgrids**

A typical DC microgrid consists of several key components:

**Renewable Energy Sources:** Solar photovoltaic (PV) systems and wind turbines are common sources that generate DC electricity.

**Energy Storage Systems:** Batteries, supercapacitors, and flywheels store excess energy generated during peak production times for use during low production periods.

**Power Electronics:** Converters and inverters manage the flow of electricity within the microgrid, ensuring compatibility between different components and facilitating control strategies.

**Load Management Systems:** These systems monitor and control the consumption of electrical energy by various loads connected to the microgrid.

### **2.3 Types of Microgrids**

Microgrids can be classified into two main types:

**2.3.1 Grid-connected Microgrids (On grid MGs):** Operate in tandem with the main grid but can disconnect during outages.

**2.3.2 Isolated Microgrids (Off grid MGs):** Function independently without connection to a larger grid network.

### **2.4 Advantages of DC Microgrids**

The advantages of implementing DC microgrids include:

**Higher Efficiency:** Direct current systems reduce conversion losses associated with alternating current (AC) systems, particularly when integrating renewable energy sources that produce DC.

**Simplified Design:** The absence of transformers simplifies the design and reduces costs associated with infrastructure.

**Enhanced Reliability:** Localized generation and storage capabilities allow for improved resilience against outages in the main grid.

## **2.4 Challenges Facing DC Microgrids**

Despite their advantages, several challenges must be addressed:

**Standardization Issues:** The lack of standardized protocols can hinder interoperability among different devices and systems within a microgrid.

**Control Strategies:** Developing effective control algorithms to manage distributed generation, storage, and load demands is complex but essential for optimal performance.

**Economic Viability:** Initial investment costs can be high; thus, economic models must demonstrate long-term benefits to encourage adoption.

## **2.5 Applications of DC Microgrids**

DC microgrids find applications in various sectors:

**Commercial Buildings:** Integrating solar PV systems with battery storage allows buildings to optimize their energy consumption while reducing reliance on grid power.

**Electric Vehicle Charging Stations:** These stations benefit from direct current supply, improving charging efficiency and reducing infrastructure costs.

**Remote Areas:** In regions lacking access to reliable power grids, DC microgrids provide an independent solution for electricity needs through local renewable resources.

## **2.6 SPECIFICATIONS**

### **2.6.1**

### **Solar**

### **Panel**

Solar panels are employed to capture solar energy. They consist of multiple solar cells connected in a series-parallel configuration. These cells are made from two types of semiconductors: p-type and n-type silicon. When sunlight hits a solar cell, it knocks electrons loose from the silicon. If this occurs within the electric field, the electrons move from the n-type layer to the p-type layer through an external circuit, generating an electric current. The resulting solar power can be stored for future use. In our prototype, a 12W, 21V solar panel is utilized to power a 12V DC load.



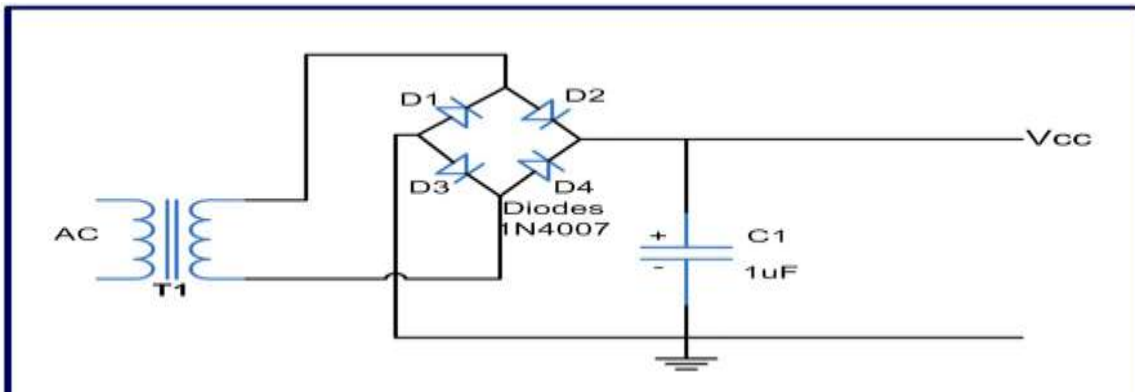
*Figure 1 PV Module*

### **2.6.2 AC to DC Converter**

To power the Arduino processor, an additional DC power source was created. The process begins by stepping down the voltage from 230V AC to 12V AC using a step-down transformer. A bridge rectifier then converts the 12V AC into 12V DC. Afterward, capacitors and a 7812 voltage regulator are used to provide a stable 12V DC supply to the Arduino processor.

Equipment used:

- Rectifiers
- Diodes
- Capacitors
- Voltage regulator 7812

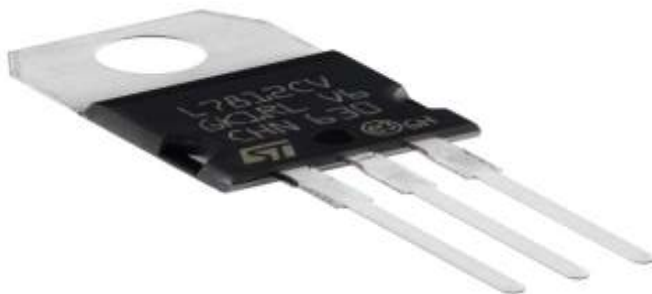


*Figure 2 Rectifier*

### 2.6.3 Voltage Regulator LM7812

The LM7812 integrated circuit (IC) provides a stable output voltage of 12V, regardless of fluctuations or variations in the input voltage, as long as it remains higher than 12V but does not exceed 35V, which is the maximum input voltage limit for this IC. Additionally, the input voltage must not fall below 14V, as this is the minimum requirement for maintaining a fixed output of 12V. While this IC is primarily designed for a fixed output, users can adjust the output voltage, if necessary, by employing two external resistors connected at the output.

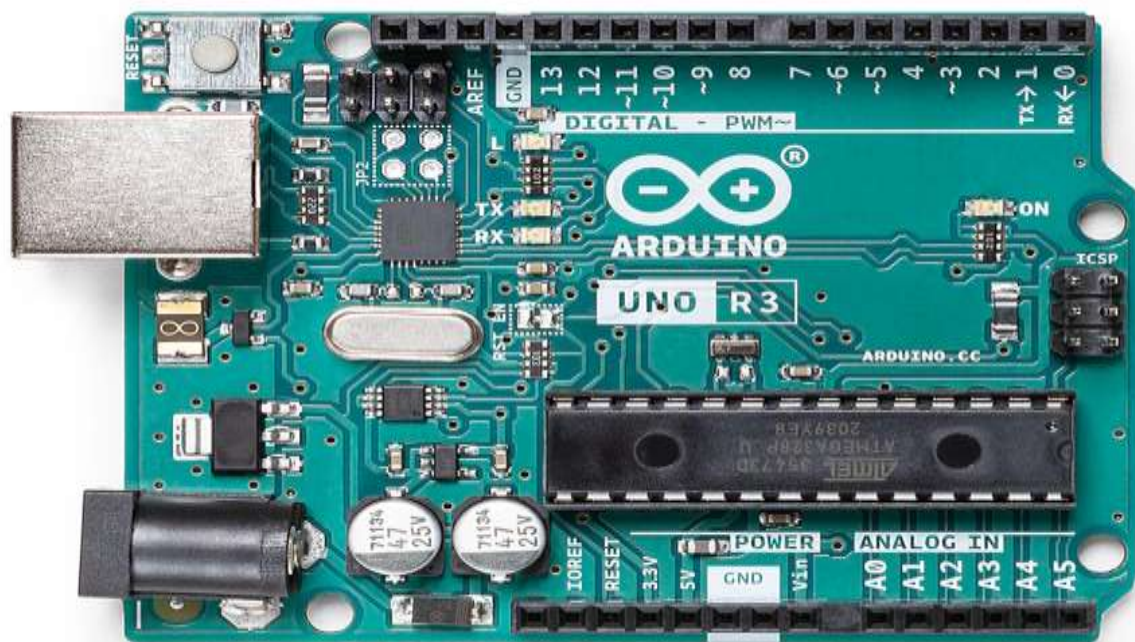
When the IC regulates voltage or reduces the input voltage, the difference between the input and output voltages is dissipated as heat. Therefore, it is essential to use an appropriate heatsink to ensure the IC operates effectively. The LM7812 can manage a maximum load of 1A to 1.5A, but the input current must be at least 2A to achieve this output range.



*Figure 3 LM7812*

### 2.6.4 Arduino UNO

The Arduino Uno is a microcontroller board built around the 8-bit ATmega328P microcontroller. In addition to the ATmega328P, the board includes several supporting components such as a crystal oscillator, serial communication interfaces, and a voltage regulator. The Arduino Uno features 14 digital input/output pins (6 of which support PWM output), 6 analog input pins, a USB connection, a power barrel jack, an ICSP header, and a reset button.



*Figure 4 Arduino Uno*

### 2.6.5 ESP8266 Wi-Fi Module (NodeMCU)

The NodeMCU ESP8266 development board incorporates the ESP-12E module, which features the ESP8266 chip equipped with a Tensilica Xtensa 32-bit LX106 RISC microprocessor. This microprocessor is capable of supporting real-time operating systems (RTOS) and operates at a clock frequency that can be adjusted between 80MHz and 160MHz. The NodeMCU is equipped with 128 kilobytes of RAM and 4MB of Flash memory for data and program storage. Its robust processing capabilities, along with built-in Wi-Fi and Bluetooth, as well as Deep Sleep Operating features, make it well-suited for

Internet of Things (IoT) applications. The NodeMCU can be powered through a Micro USB jack or the VIN pin (external supply pin) and supports UART, SPI, and I2C communication interfaces.



*Figure 5 Nodemcu*

### **2.6.6 ACS712 Current Sensor**

The ACS712 Current Sensor Module, designed for a 5A range, features a low-offset, linear Hall effect circuit with a copper conduction path positioned close to the surface of the die. This module is built around the ACS712 sensor, which is capable of accurately measuring both AC and DC current. It can detect maximum currents of up to 5A, and the resulting current signal can be accessed through the analog I/O port of the Arduino.



*Figure 6 ACS712 Current Sensor*

### 2.6.7 Voltage sensor

A voltage sensor is designed to measure and monitor the voltage present in a given object. These sensors can assess both AC and DC voltage levels. The input to the sensor is the voltage itself, while the output can take various forms, such as switches, analog voltage signals, current signals, or audible signals. The sensor has an input voltage range of 0V to 25V, with a detection range of 0.02445V to 25V.



*Figure 7 Voltage Sensor*

### 2.6.8 4-Channel 5V Relay

Each channel on a 5V 4-channel relay interface board requires a driver current of 15-20mA. This board can be utilized to control various high-current appliances and devices. It includes high-current relays capable of operating under AC250V at 10A or DC30V at 10A. Additionally, it features a standard interface that allows for direct control by a microcontroller.

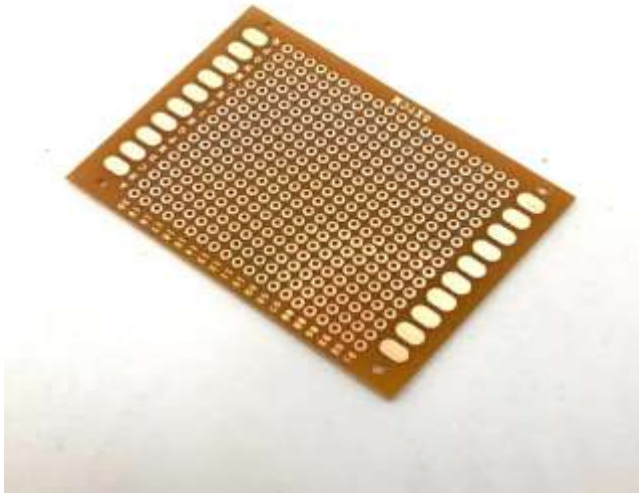


*Figure 8 4-Channel relay Module*



### 2.6.9 PCB board

A PCB board is a crucial component in modern electronics, providing mechanical support and electrical connections for electronic components to form functional circuits. Its design and manufacturing processes ensure reliable and efficient operation of electronic devices across various industries.



*Figure 9 PCB board*

### 2.6.10 Jumper wires

Jumper wires are essential tools in electronics for creating temporary connections between components during prototyping, testing, and development stages. They facilitate easy assembly, modification, and debugging of circuits without the need for soldering, making them invaluable in electronics education and engineering projects.



*Figure 10 Jumper wire*

### 2.6.11 Blynk Application

Blynk is a platform that facilitates internet-based control of devices such as Arduino, Raspberry Pi, and others through iOS and Android applications. Users can easily design a graphical interface for their projects on a digital dashboard by simply dragging and dropping widgets. Blynk allows anyone to connect their hardware to the cloud, creating no-code applications for iOS, Android, and the web. This enables users to analyze real-time and historical data from their devices, control them remotely from anywhere in the world, receive crucial notifications, and much more.

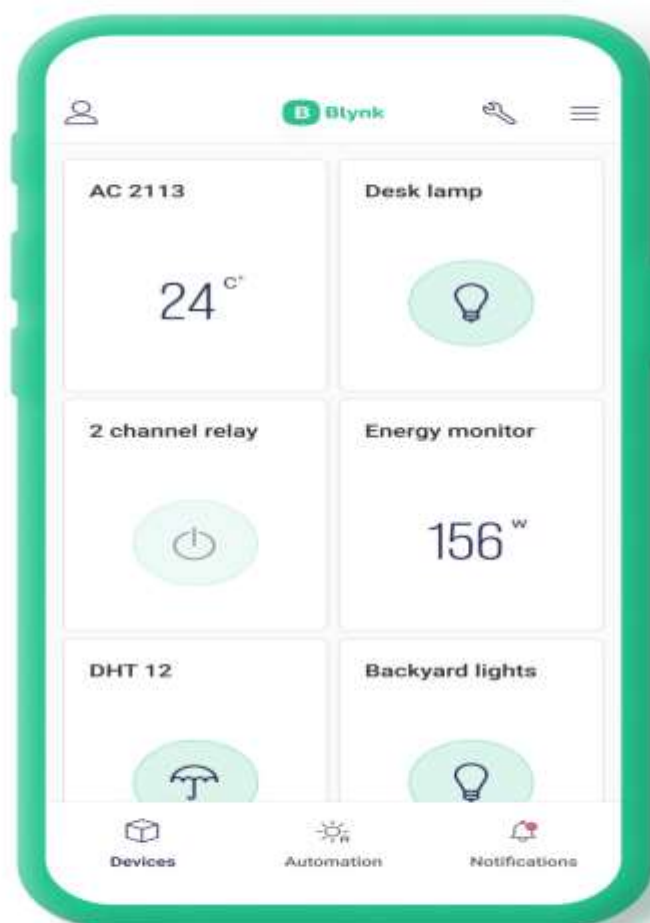


Figure 11 Blynk App

### 2.6.12 Microfarad capacitor of 25V (1 pcs)

The 1000 microfarad, 25V capacitor ensures voltage stability, filters noise, and provides energy storage, contributing to the smooth and reliable operation of the system.



*Figure 12 1000uF capacitor*

### 2.6.13 Load

This cool white bulb offers great value for money and a good quality light. It directly replaces our older 12v DC Compact florescent bulbs with a crisper light.



*Figure 13 Bulb*

## **CHAPTER 3: RESEARCH METHODOLOGY**

### **3.1 Introduction**

This chapter outlines the research methodology employed to investigate and develop the proposed DC microgrid system. The methodology encompasses the research design, data collection methods, analytical techniques, and validation procedures used to address the objectives outlined in Chapter 1. The goal is to ensure a systematic approach to developing a robust DC microgrid model that meets the defined criteria for efficiency, reliability, and sustainability.

### **3.2 Research Design**

The research design for this project is a mixed-method approach that combines both quantitative and qualitative methodologies. This design is chosen to leverage the strengths of numerical analysis and theoretical exploration, providing a comprehensive understanding of DC microgrid systems.

**3.2.1 Quantitative Analysis:** Focuses on the mathematical modeling and simulation of the DC microgrid system. This includes load flow analysis, optimization of power distribution, and performance evaluation under different operating conditions.

**3.2.2 Qualitative Analysis:** Involves reviewing existing literature, case studies, and theoretical models to understand the principles, challenges, and advancements in DC microgrid technology.

### **3.3 Data Collection Methods**

Data collection for this project will be conducted through the following methods:

**3.3.1 Literature Review:** Comprehensive review of academic papers, technical reports, and industry publications related to DC microgrids. This will provide insights into current technologies, methodologies, and research gaps.

**3.3.2 Simulation Data:** Data will be gathered from simulations of DC microgrid models using software tools such as MATLAB/Simulink, PSCAD, or HOMER. These simulations will model various scenarios and configurations to evaluate system performance.

**3.3.3 Case Studies:** Analysis of existing DC microgrid implementations to gather real-world performance data, operational challenges, and best practices.

Expert Interviews: Interviews with professionals and researchers in the field of microgrids to gain expert opinions and validate the findings from simulations and case studies.

### **3.4 Analytical Techniques**

The following analytical techniques will be employed to analyse the collected data:

**Mathematical Modelling:** Development of mathematical models to describe the behaviour of the DC microgrid. This includes load flow equations, control algorithms, and optimization routines.

**Simulation Analysis:** Using simulation results to assess system performance metrics such as efficiency, stability, and reliability. Sensitivity analysis will be performed to evaluate how different parameters affect the system.

**Statistical Analysis:** Application of statistical methods to interpret simulation data and compare performance metrics. Techniques such as regression analysis and hypothesis testing will be used to draw conclusions.

**Comparative Analysis:** Evaluating the proposed DC microgrid model against existing systems and benchmarks. This will help in identifying the advantages and limitations of the proposed solution.

### **3.5 Validation and Verification**

To ensure the accuracy and reliability of the research findings, the following validation and verification procedures will be implemented:

**Model Verification:** Verification of mathematical models and simulations through consistency checks and comparison with theoretical results.

**Validation through Case Studies:** Cross-referencing simulation results with data from real-world case studies to validate the practical applicability of the model.

**Expert Review:** Soliciting feedback from industry experts and academic peers to review the research methodology and findings. Their input will be used to refine the models and ensure the validity of the results.

**Sensitivity Analysis:** Conducting sensitivity analysis to test the robustness of the model against variations in key parameters and assumptions.

### **3.6 Ethical Considerations**

The research will adhere to ethical standards, ensuring that all data collection and analysis processes are conducted with integrity and transparency. Any proprietary or sensitive information obtained during expert interviews or case studies will be handled confidentially.

### **3.7 Summary**

This chapter has detailed the research methodology for investigating DC microgrids, encompassing the research design, data collection methods, analytical techniques, and validation procedures. By employing a mixed-method approach and rigorous validation processes, the research aims to develop a comprehensive and reliable DC microgrid model that addresses the project's objectives and contributes valuable insights to the field.

## CHAPTER 4: SYSTEM DESIGN ANALYSIS AND IMPLEMENTATION

### 4.0 Introduction

A hybrid power generation system combines two renewable energy sources, such as solar and utility grid. Other sources (such as Wind, diesel Generators) can be added also if available. This approach enhances the system's efficiency and power reliability. A solar panel with a 12V rating is used to capture solar energy, while power from Utility grid is stepped down and rectified to provide additional voltage. A battery backup is incorporated to meet load demand when energy from the solar panel is insufficient or utility grid is unavailable. Each energy source is equipped with a voltage sensor to monitor voltage levels at the source. The data is processed by an Arduino UNO microcontroller. Additionally, a current sensor is placed at the load end to measure the current flowing into the load. The microcontroller communicates with the Blynk server via Node MCU, which acts as a bidirectional serial interface. The system's circuit diagram is shown under the diagram section.

Figure 11 illustrates the flowchart of the DC microgrid automation system, which considers three power sources. After detecting the voltage values from each source, the voltage sensor sends the data to the Arduino. Based on these readings, the relay unit selects the source with the optimal voltage. The power from the chosen source passes through a buck converter and is then sent to a current sensor, which measures the current. This measured current, along with the voltage values, is transmitted to a Wi-Fi module via the Arduino. The Blynk app displays both the received voltage and current data.

The proposed system is divided into two main components: hardware and software. The hardware includes a solar panel, utility grid, voltage and current sensors, an Arduino UNO, an ESP8266 Wi-Fi module, and a relay. The software side consists of the Arduino IDE and the Blynk app.

This system integrates a microgrid automation setup featuring various power sources, a sensor array, control unit, relay mechanism, and a mobile application interface powered by the Internet of Things (IoT). Power is sourced from solar and wind energy, and a battery backup is available for use in the event of a power failure. The sensor array includes voltage and current sensors, while the control unit comprises a microcontroller, Wi-Fi module, and a set of relays tailored to the system's needs.

The voltage and current sensors measure their respective values using the voltage divider method across all power sources. These measurements are processed by the microcontroller, which makes decisions based on pre-programmed logic. The current sensor detects the load's power consumption using the Hall effect, providing insights into demand, and sends the data to the microcontroller. The relays, controlled by the microcontroller, switch the load between different power sources or disconnect it if an issue arises. Users can monitor these operations in real time through a mobile application that displays live data via a dashboard. This is made possible through the Wi-Fi module, which connects the microcontroller to the IoT application. The app also enables users to configure various thresholds and limits.

Users can set high and low voltage thresholds within the Blynk app, as well as define the maximum load a source can handle. If a source's voltage falls below or exceeds the preset limits, the microcontroller shifts the load to another power source by activating the relays. Should both the solar and wind sources provide insufficient power, the system automatically switches to the battery backup.

The system also switches the load to an alternative power source when the demand exceeds the capacity of the current source. In the event of a complete power failure or an exceptionally high demand that none of the sources can meet, the load is disconnected from all sources, ensuring system safety.

#### **4.1 Calculations**

The peak voltage produced by Diodes after rectifying the voltage is given by:

$$V_{\text{peak}} = V_{\text{rms}} \times \sqrt{2} = 12 \times 1.414 \approx 16.97\text{V}$$

The DC voltage is then given by:

$$V_{\text{DC}} \approx V_{\text{peak}} - 1.4\text{V} = 16.97\text{V} - 1.4\text{V} = 15.57\text{V}$$

For Solar:

$$V_{\text{peak}} = 17.9$$

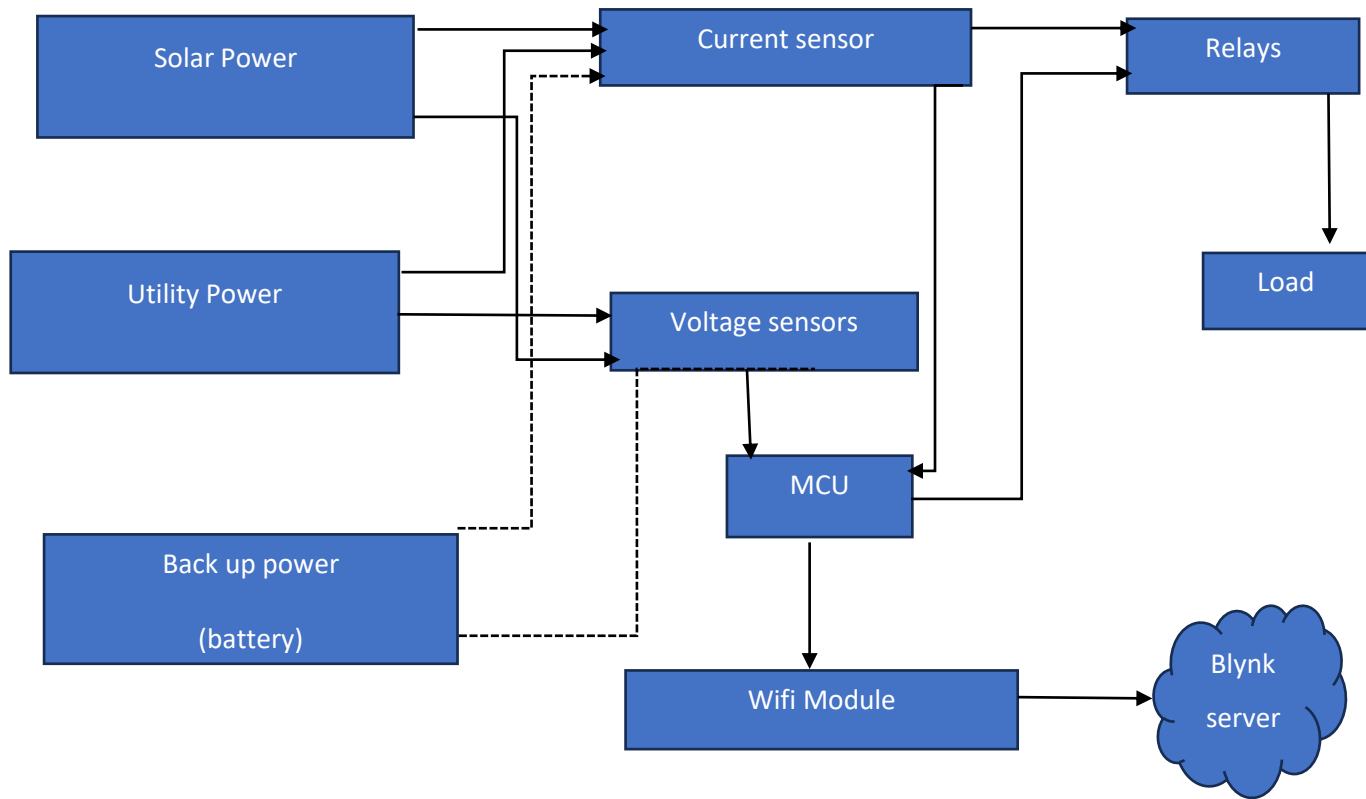
$$P_{\text{peak}} = 135$$

$$I_{\text{peak}} = \frac{P_{\text{peak}}}{V_{\text{peak}}} = \frac{135}{17.9} = 7.6$$



## 4.2 Drawing

### 4.2.1 Block Diagram



### 4.2.2 Flowchart of the system

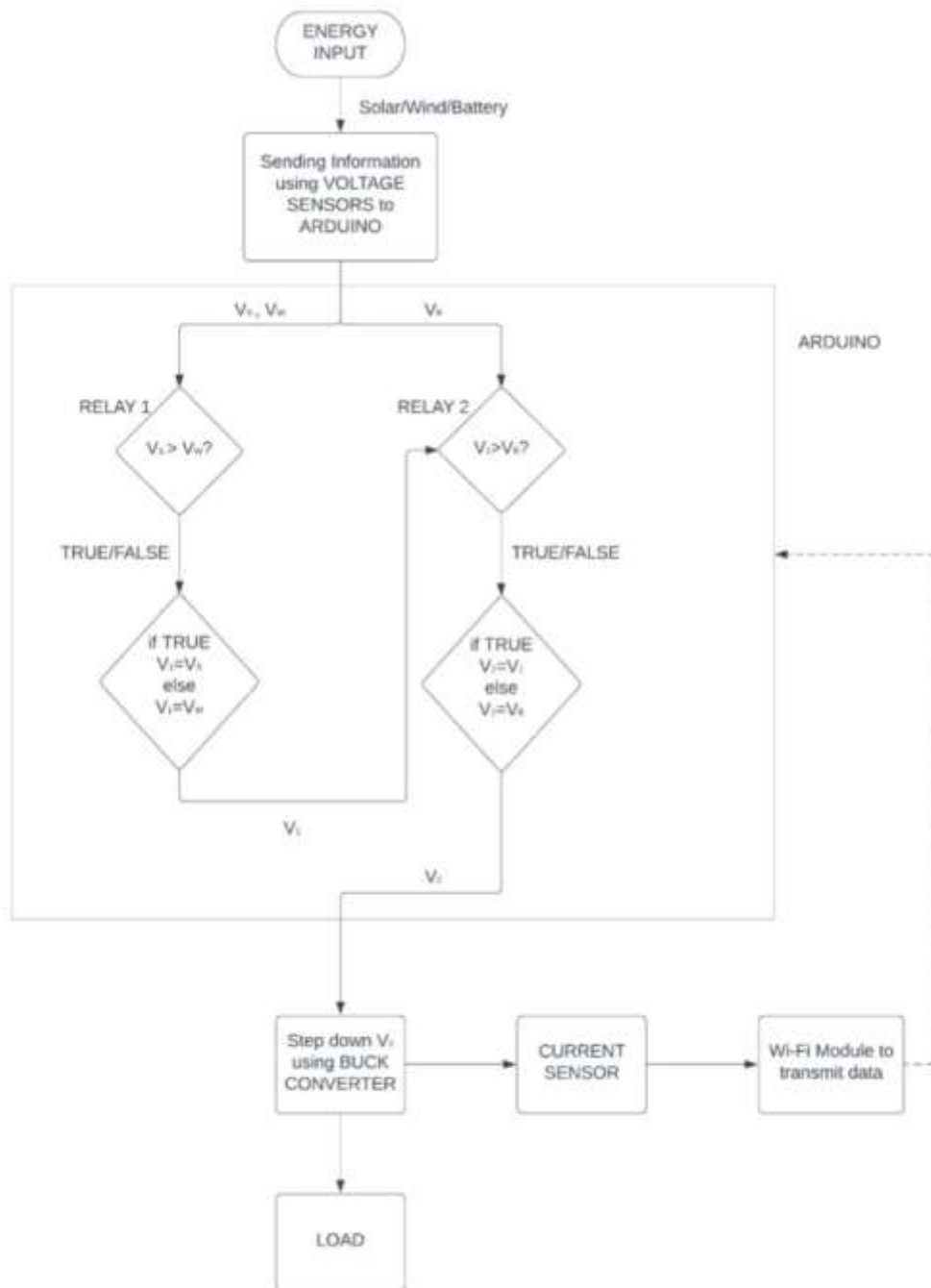


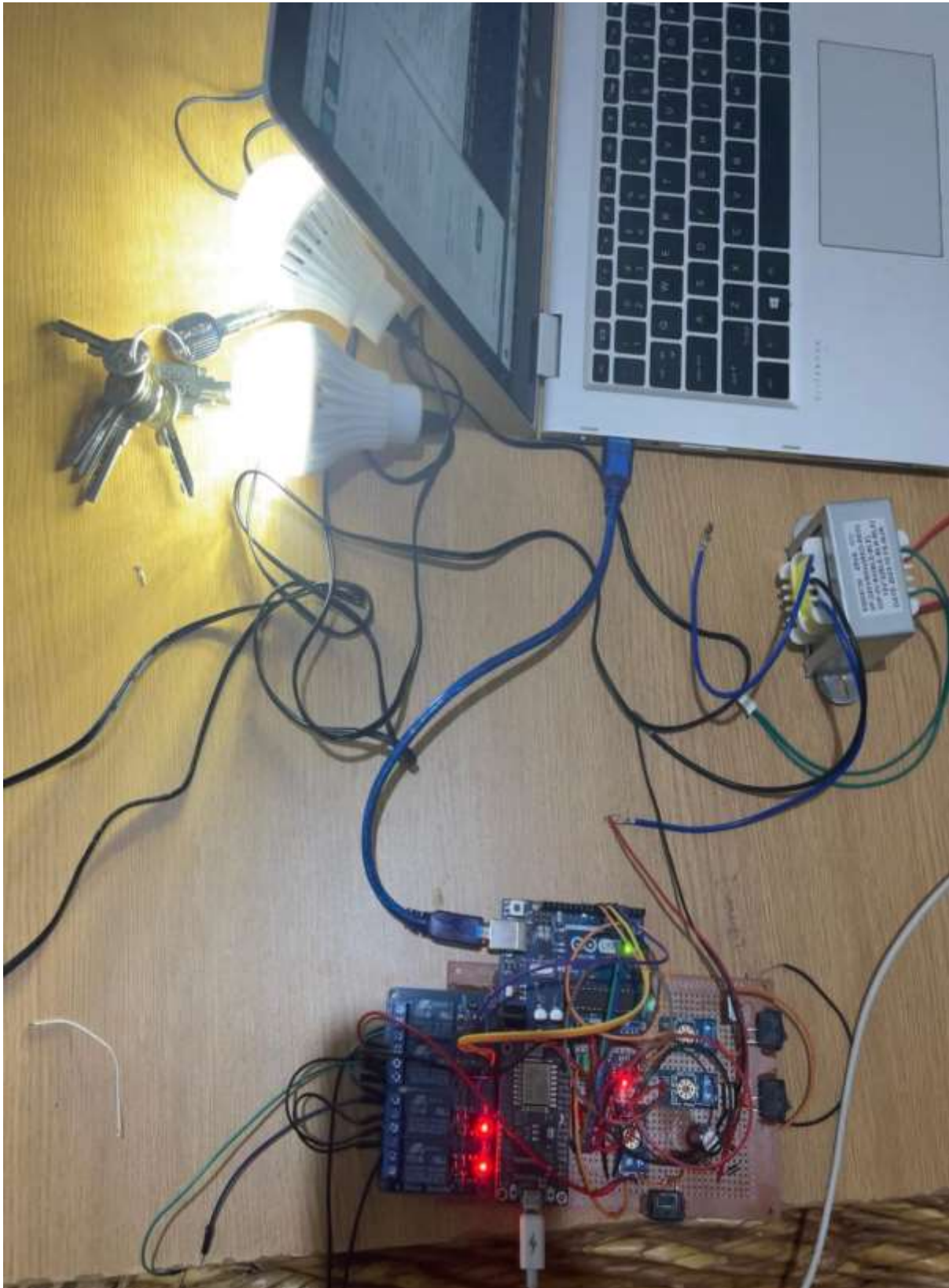
Figure 14 Flow Chart of the Hybrid System

### 4.3 Cost estimation

The cost estimation of a project refers to the process of predicting the expenses that will be incurred to complete the project successfully. It involves identifying and estimating the costs associated with various resources and activities required for project execution.

<b>Components</b>	<b>Pcs</b>	<b>Unit cost</b>	<b>Total cost</b>
<b>Arduino UNO</b>	<b>1</b>	<b>15,000frw</b>	<b>15,000frw</b>
<b>Voltage Sensor</b>	<b>3</b>	<b>6,000frw</b>	<b>18,000frw</b>
<b>Current sensor</b>	<b>1</b>	<b>6,500frw</b>	<b>6,500frw</b>
<b>Wi-Fi Module(Nodemcu)</b>	<b>1</b>	<b>11,000frw</b>	<b>11,00frw</b>
<b><u>Battery</u></b>	<b>2</b>	<b>2,500frw</b>	<b>5,000frw</b>
<b>Transformer (220v/12v)</b>	<b>1</b>	<b>11,000frw</b>	<b>11,000frw</b>
<b>Diodes</b>	<b>4</b>	<b>500frw</b>	<b>2,000frw</b>
<b>4-channel relay module</b>	<b>1</b>	<b>8,000frw</b>	<b>8,000frw</b>
<b>Capacitor</b>	<b>1</b>	<b>600frw</b>	<b>600</b>
<b><u>Load</u></b>	<b>5</b>	<b>300frw</b>	<b>1,500frw</b>
<b>PCB board</b>	<b>1</b>	<b>2.000frw</b>	<b>2,000frw</b>
<b>Jumper wires</b>	<b>50</b>	<b>100frw</b>	<b>5,000frw</b>
<b>Voltage regulator (L7812)</b>	<b>3</b>	<b>500frw</b>	<b>1,500frw</b>
<b>Bulbs</b>	<b>2</b>	<b>2,500frw</b>	<b>5,000frw</b>
<b>TOTAL</b>	<b>46</b>	<b>51,000frw</b>	<b>92,100frw</b>

## 4.5 Implementation



*Figure 15 Implementation*

## 4.6 Circuit

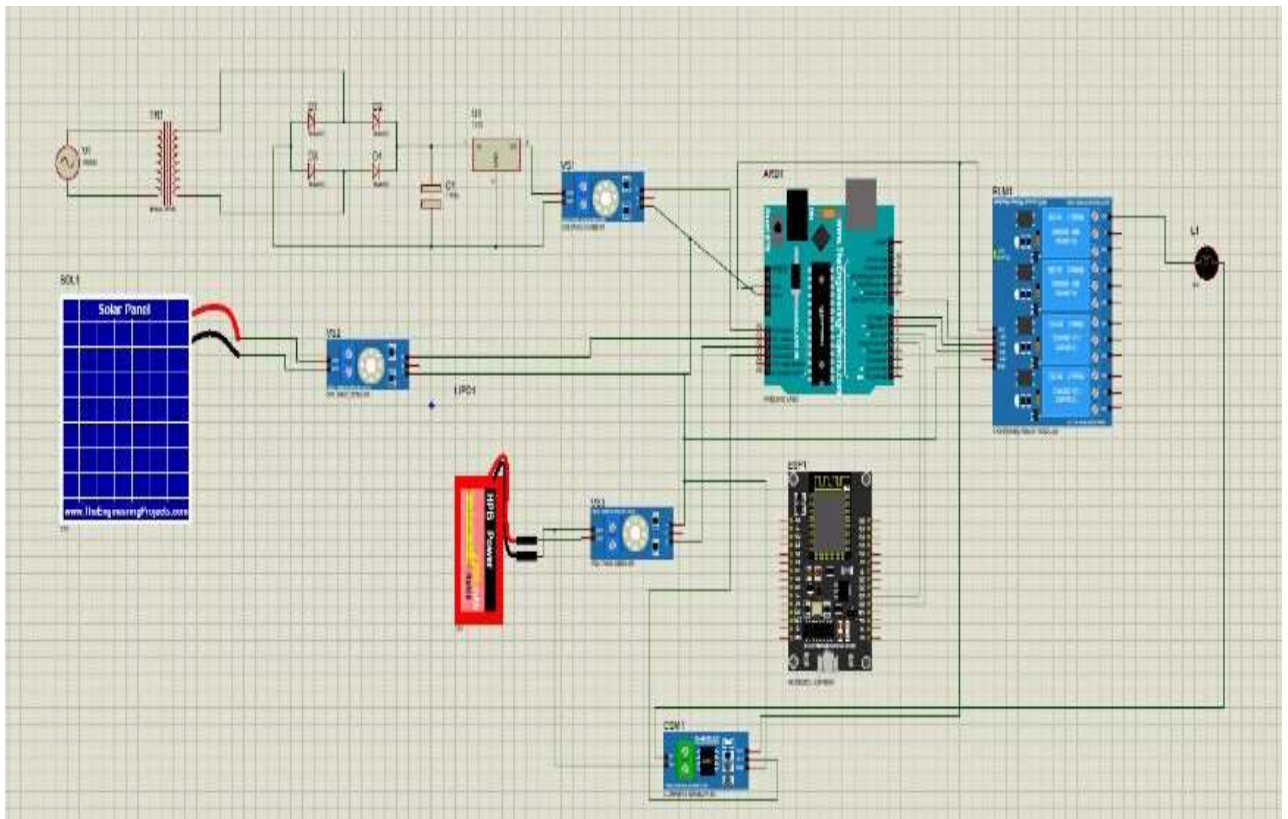


Figure 16 Circuit Diagram

## **CHAPTER 5: CONCLUSION AND RECOMMENDATION**

### **5.0 Introduction**

The energy sector is experiencing a significant shift towards sustainability, energy efficiency, and the adoption of renewable energy sources. DC microgrids have emerged as a promising solution to overcome the limitations of conventional AC systems, particularly in scenarios that require the integration of renewable energy, energy storage, and decentralized power generation. This chapter presents a summary of the findings from this study on DC microgrids and provides recommendations for future advancements and implementations.

### **5.1 Conclusion**

This research has investigated the potential and technical feasibility of DC microgrids in various applications, particularly in the realm of renewable energy systems. The study highlights several advantages of DC microgrids, including increased efficiency, reduced energy conversion losses, and better integration of renewable energy sources. The findings indicate that DC microgrids present an effective approach for energy distribution, especially in systems that rely on renewable energy sources like solar and wind. Additionally, the integration of energy storage systems ensures a stable and reliable power supply, even in regions with variable energy demand or limited access to conventional grids.

Key technical components such as system architecture, control strategies, and power electronics integration have been thoroughly addressed. The development of effective energy management systems has further optimized the performance of DC microgrids, positioning them as a promising solution for future power distribution networks.

Nonetheless, challenges remain, particularly regarding scalability, standardization, and cost-effectiveness. As the demand for sustainable energy continues to rise, these challenges must be addressed through ongoing research and innovation.

### **5.2 Recommendations**

To enhance the development and adoption of DC microgrids, the following recommendations are proposed:

- **Standardization of Components:** Establishing standardized protocols and components will improve system compatibility, ease design, and reduce costs.

- **Advancement in Power Electronics:** Further research in power electronics, especially DC-DC converters and control systems, will boost efficiency and reliability.
- **Policy Support:** Governments should introduce policies and incentives to promote DC microgrid adoption, such as subsidies for renewable energy integration.
- **Cost-Effective Storage Solutions:** Focus on developing affordable and efficient energy storage technologies to improve system performance.
- **Pilot Projects:** Real-world testing and pilot projects will provide valuable data for scalability and system improvement.
- **Education and Awareness:** Programs to educate engineers, policymakers, and the public on DC microgrid benefits will help drive adoption.

### **5.3 Suggestion for further study**

The public resource monitoring system has good prospects going forward, especially in the health and environmental sectors. There are many places where this system is necessary. It may involve the toilets, hospitals, or school that travelers use when traveling. We can include a payment system to assist with toilet and component maintenance as well.

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## SOURCE CODE

### ARDUINO CODE

```
#include <SoftwareSerial.h>

// Pin definitions

#define SOLAR_VOLTAGE_PIN A0

#define UTILITY_VOLTAGE_PIN A1

#define BATTERY_VOLTAGE_PIN A2

#define LOAD_CURRENT_PIN A3

#define SOLAR_RELAY_PIN 8

#define UTILITY_RELAY_PIN 7

#define BATTERY_RELAY_PIN 6

#define LOAD_RELAY_PIN 5

SoftwareSerial espSerial(5, 4); // RX, TX

// Global variables for thresholds

float highVoltageThreshold = 13.0;

float lowVoltageThreshold = 10.0;

float solarUtilityLoadLimit = 2.0;

float batteryLoadLimit = 5.0;

// Function prototypes

float readVoltage(int pin);

float readCurrent();

void selectPowerSource(float solarVoltage, float utilityVoltage, float batteryVoltage, float
loadCurrent,
float lowVoltageThreshold, float solarUtilityLoadLimit, float batteryLoadLimit);

void displayReadings(float solar, float utility, float battery, float current);
```

```
void displayRelayStatus()

void setup() {

  Serial.begin(9600);

  espSerial.begin(9600);

  Serial.println("Power Management System Starting...");

  pinMode(SOLAR_RELAY_PIN, OUTPUT);

  pinMode(UTILITY_RELAY_PIN, OUTPUT);

  pinMode(BATTERY_RELAY_PIN, OUTPUT);

  pinMode(LOAD_RELAY_PIN, OUTPUT);

  // Initially connect load to utility

  digitalWrite(UTILITY_RELAY_PIN, HIGH);

  digitalWrite(LOAD_RELAY_PIN, HIGH);

  Serial.println("Setup complete. Initial state: Utility power");

}

void loop() {

  float solarVoltage = readVoltage(SOLAR_VOLTAGE_PIN);

  float utilityVoltage = readVoltage(UTILITY_VOLTAGE_PIN);

  float batteryVoltage = readVoltage(BATTERY_VOLTAGE_PIN);

  float loadCurrent = readCurrent();

  // Display readings on Serial Monitor

  displayReadings(solarVoltage, utilityVoltage, batteryVoltage, loadCurrent);

  // Send data to NodeMCU

  espSerial.print(solarVoltage);

  espSerial.print(",");
```

```
espSerial.print(utilityVoltage);

espSerial.print(",");

espSerial.print(batteryVoltage);

espSerial.print(",");

espSerial.println(loadCurrent);

// Check for commands from NodeMCU

if (espSerial.available()) {

    String command = espSerial.readStringUntil('\n');

    command.trim()

    if (command == "ISOLATE") {

        Serial.println("Received ISOLATE command");

        isolateLoad();

    } else {

        // Parse thresholds

        highVoltageThreshold = command.substring(0, command.indexOf(',')).toFloat();

        command = command.substring(command.indexOf(',') + 1);

        lowVoltageThreshold = command.substring(0, command.indexOf(',')).toFloat();

        command = command.substring(command.indexOf(',') + 1);

        solarUtilityLoadLimit = command.substring(0, command.indexOf(',')).toFloat();

        batteryLoadLimit = command.substring(command.indexOf(',') + 1).toFloat();

        Serial.println("Received new thresholds:");

        Serial.print("High Voltage: "); Serial.println(highVoltageThreshold);

        Serial.print("Low Voltage: "); Serial.println(lowVoltageThreshold);

        Serial.print("Solar/Utility Load Limit: "); Serial.println(solarUtilityLoadLimit);
```

```

Serial.print("Battery Load Limit: "); Serial.println(batteryLoadLimit);

selectPowerSource(solarVoltage, utilityVoltage, batteryVoltage, loadCurrent,
                  lowVoltageThreshold, solarUtilityLoadLimit, batteryLoadLimit);
}
}

displayRelayStatus();

Serial.println("-----");

delay(30000); // Update every second
}

float readVoltage(int pin) {
  int rawValue = analogRead(pin);

  return map(rawValue, 0, 1023, 0, 25); // Assuming 0-25V range
}

float readCurrent() {
  int rawValue = analogRead(LOAD_CURRENT_PIN);

  return map(rawValue, 0, 1023, 0, 5); // Assuming 0-5A range for ACS712
}

void selectPowerSource(float solarVoltage, float utilityVoltage, float batteryVoltage, float
loadCurrent, float lowVoltageThreshold, float solarUtilityLoadLimit, float
batteryLoadLimit) { if (loadCurrent > solarUtilityLoadLimit) {

  if (batteryVoltage > lowVoltageThreshold && loadCurrent <= batteryLoadLimit) {

    // Switch to battery

    Serial.println("Switching to battery power (high load)");

```

```
digitalWrite(SOLAR_RELAY_PIN, LOW);  
digitalWrite(UTILITY_RELAY_PIN, LOW);  
digitalWrite(BATTERY_RELAY_PIN, HIGH);  
} else {  
    Serial.println("Load too high, isolating");  
    isolateLoad();  
}  
} else if (solarVoltage > utilityVoltage && solarVoltage > lowVoltageThreshold) {  
    // Use solar  
    Serial.println("Switching to solar power");  
    digitalWrite(SOLAR_RELAY_PIN, HIGH);  
    digitalWrite(UTILITY_RELAY_PIN, LOW);  
    digitalWrite(BATTERY_RELAY_PIN, LOW);  
} else if (utilityVoltage > lowVoltageThreshold) {  
    // Use utility power  
    Serial.println("Switching to utility power");  
    digitalWrite(SOLAR_RELAY_PIN, LOW);  
    digitalWrite(UTILITY_RELAY_PIN, HIGH);  
    digitalWrite(BATTERY_RELAY_PIN, LOW);  
} else {  
    // Use battery as fallback  
    Serial.println("Switching to battery power (fallback)");  
    digitalWrite(SOLAR_RELAY_PIN, LOW);  
    digitalWrite(UTILITY_RELAY_PIN, LOW);
```

```
    digitalWrite(BATTERY_RELAY_PIN, HIGH);
}
}

void isolateLoad() {
    Serial.println("Isolating load");
    digitalWrite(SOLAR_RELAY_PIN, LOW);
    digitalWrite(UTILITY_RELAY_PIN, LOW);
    digitalWrite(BATTERY_RELAY_PIN, LOW);
    digitalWrite(LOAD_RELAY_PIN, LOW);
}

void displayReadings(float solar, float utility, float battery, float current) {
    Serial.println("\n--- Current Readings ---");
    Serial.print("Solar Voltage: "); Serial.print(solar, 2); Serial.println("V");
    Serial.print("Utility Voltage: "); Serial.print(utility, 2); Serial.println("V");
    Serial.print("Battery Voltage: "); Serial.print(battery, 2); Serial.println("V");
    Serial.print("Load Current: "); Serial.print(current, 2); Serial.println("A");
}

void displayRelayStatus() {
    Serial.println("--- Relay Status ---");
    Serial.print("Solar Relay: "); Serial.println(digitalRead(SOLAR_RELAY_PIN) ? "ON" :
"OFF");
    Serial.print("Utility Relay: "); Serial.println(digitalRead(UTILITY_RELAY_PIN) ?
"ON" : "OFF");
    Serial.print("Battery Relay: "); Serial.println(digitalRead(BATTERY_RELAY_PIN) ?
"ON" : "OFF");
}
```

```

Serial.print("Load Relay: "); Serial.println(digitalRead(LOAD_RELAY_PIN) ? "ON" :
"OFF");

}

```

### ESP 8266 CODE

```

// Template ID, Name & Auth token

#define BLYNK_TEMPLATE_ID "TMPL2PZo7PITD"

#define BLYNK_TEMPLATE_NAME "Solar voltmeter"

#define BLYNK_AUTH_TOKEN "Cyhu6kqyJgbzwGjdndOoYyswnwDSNAdn"

#define BLYNK_PRINT Serial // Enables Serial Monitor

#include <ESP8266WiFi.h>

#include <BlynkSimpleEsp8266.h>

#include <SoftwareSerial.h>

// WiFi credentials

const char* ssid = "iPhone12";

const char* pass = "12345678";

SoftwareSerial arduinoSerial(D8, D7); // RX, TX

// Threshold values (can be adjusted via Blynk app)

float highVoltageThreshold = 13.0;

float lowVoltageThreshold = 10.0;

float solarUtilityLoadLimit = 2.0;

float batteryLoadLimit = 5.0;

String activeSource = "Battery";

void setup() {

  Serial.begin(115200);

  arduinoSerial.begin(9600);

```



```
Serial.println("Connecting to WiFi...");

WiFi.begin(ssid, pass);

while (WiFi.status() != WL_CONNECTED) {

    delay(500);

    Serial.print(".");

}

Serial.println("\nWiFi connected");

Blynk.config(BLYNK_AUTH_TOKEN);

bool result = Blynk.connect();

if (result) {

    Serial.println("Connected to Blynk server");

} else {

    Serial.println("Failed to connect to Blynk server");

}

}

void loop() {

    if (Blynk.connected()) {

        Blynk.run();

    } else {

        Serial.println("Reconnecting to Blynk...");

        Blynk.connect();

    }

}
```

```

if (arduinoSerial.available()) {

  String data = arduinoSerial.readStringUntil('\n');

  data.trim();

  // Parse the received data

  float solarVoltage = data.substring(0, data.indexOf(',')).toFloat();

  data = data.substring(data.indexOf(',') + 1);

  float utilityVoltage = data.substring(0, data.indexOf(',')).toFloat();

  data = data.substring(data.indexOf(',') + 1);

  float batteryVoltage = data.substring(0, data.indexOf(',')).toFloat();

  float loadCurrent = data.substring(data.indexOf(',') + 1).toFloat();

  // Send sensor data to Blynk app

  Blynk.virtualWrite(V0, utilityVoltage);

  Blynk.virtualWrite(V1, solarVoltage);

  Blynk.virtualWrite(V2, batteryVoltage);

  Blynk.virtualWrite(V3, loadCurrent);

  // Check for anomalies

  if (solarVoltage > highVoltageThreshold || utilityVoltage > highVoltageThreshold ||
batteryVoltage > highVoltageThreshold) {

    arduinoSerial.println("ISOLATE");

    Blynk.logEvent("overvoltage_alert", "Anomaly detected: Overvoltage! Load
isolated.");

    activeSource = "Isolated";

  } else if (solarVoltage < lowVoltageThreshold && utilityVoltage <
lowVoltageThreshold && batteryVoltage < lowVoltageThreshold) {

```

```
arduinoSerial.println("ISOLATE");

    Blynk.logEvent("undervoltage_alert", "Anomaly detected: Undervoltage! Load
isolated.");

    activeSource = "Isolated";

} else {

    // Send thresholds to Arduino for power source selection

    arduinoSerial.print(highVoltageThreshold);

    arduinoSerial.print(",");

    arduinoSerial.print(lowVoltageThreshold);

    arduinoSerial.print(",");

    arduinoSerial.print(solarUtilityLoadLimit);

    arduinoSerial.print(",");

    arduinoSerial.println(batteryLoadLimit);

    // Determine active source based on voltage readings

    if (loadCurrent > solarUtilityLoadLimit) {

        if (batteryVoltage > lowVoltageThreshold && loadCurrent <= batteryLoadLimit) {

            activeSource = "Battery";

        } else {

            activeSource = "Isolated";

        }

    } else if (solarVoltage > utilityVoltage && solarVoltage > lowVoltageThreshold) {

        activeSource = "Solar";

    } else if (utilityVoltage > lowVoltageThreshold) {

        activeSource = "Utility";

    } else {
```

```
    activeSource = "Battery";  
  }  
}  
  
Blynk.virtualWrite(V4, activeSource);  
}  
}  
  
// Blynk app callbacks for adjusting thresholds  
  
BLYNK_WRITE(V5) {  
  highVoltageThreshold = param.asFloat();  
}  
  
BLYNK_WRITE(V6) {  
  lowVoltageThreshold = param.asFloat();  
}  
  
BLYNK_WRITE(V7) {  
  solarUtilityLoadLimit = param.asFloat();  
}  
  
BLYNK_WRITE(V8) {  
  batteryLoadLimit=param.asFloat();}
```

