ELECTRICITY GENERATION FROM EXHUST STEAM OF A STEAM TURBINE GENERATOR

Project Submitted
By
Sifatuzzaman Niloy
ID: 21-92189-3

Under the Supervision of

Dr. Mohammad Towhidul Alam
Associate Professor
American International University - Bangladesh

Department of
Electrical and Electronic Engineering
Faculty of Engineering
American International University - Bangladesh

Master of Engineering in Electrical and Electronic Engineering
Faculty of Engineering
American International University - Bangladesh
Fall Semester 2022-2023,
July, 2023

ELECTRICITY GENERATION FROM EXHUST STEAM OF A STEAM TURBINE GENERATOR

A project submitted to the Electrical and Electronic Engineering Department of the Engineering Faculty, American International University - Bangladesh (AIUB) in partial fulfillment of the requirements for the degree of Master of Engineering in Electrical and Electronic Engineering.

Sifatuzzaman Niloy **ID: 21-92189-3**

Department of
Electrical and Electronic Engineering
Faculty of Engineering
American International University - Bangladesh

Fall Semester 2022-2023,
July, 2023

DECLARATION

This is to certify that this project is my original work. No part of this work has been submitted elsewhere partially or fully for the award of any other degree or diploma. Any material reproduced in this project has been properly acknowledged.

Student's name & signature

Sifatuzzaman Niloy

APPROVAL

The Thesis titled "**Electricity Generation from Exhaust Steam of a Steam Turbine Generator**" has been submitted to the following respected members of the Board of Examiners of the Faculty of Engineering in partial fulfillment of the requirements for the **degree of Master of Engineering in Electrical and Electronic Engineering** on **July, 2023** by the following student and has been accepted as satisfactory.

Sifatuzzaman Niloy **ID: 21-92189-3**

30/7/2023

Supervisor
Dr. Mohammad Towhidul Alam
Associate Professor
Faculty of Engineering
American International University-Bangladesh

External Supervisor
Abu Hena MD. Shatil
Assistant Professor
Faculty of Engineering
American International University-Bangladesh

07.08.23

Dr. Mohammad Nasir Uddin, PEng.
Head of the Department (Graduate Program)
Faculty of Engineering
American International University-Bangladesh

for, Mannan

Prof. Dr. ABM Siddique Hossain
Dean
Faculty of Engineering
American International University-Bangladesh

ACKNOWLEDGEMENT

Firstly, I am very grateful to Allah for protecting and empowering me to do this work. I would like to express my deepest gratitude to my supervisor **Dr. Mohammad Towhidul Alam,** Associate Professor, Faculty of Engineering, American International University-Bangladesh for his continuous support and encouragement. I would like to express my appreciation to my external supervisor **Abu Hena MD. Shatil**, Assistant Professor, Faculty of Engineering, American International University-Bangladesh for his suggestions and help. I would also like to thank **Prof. Dr. ABM Siddique Hossain**, Dean, Faculty of Engineering, American International University-Bangladesh for accepting this project. Finally, I would also very thankful to **Prof. Dr. Md. Abdur Rahman**, Pro-vice chancellor, American International University – Bangladesh, for giving us the opportunity to work on this project. At the end, I am grateful to my parents who have encouraged me to do the work. I would also like to thank my classmates and colleagues who have helped me by providing information.

Sifatuzzaman Niloy

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Electricity is a vital source of energy that powers many aspects of modern life, from homes and businesses to transportation and industry. Fossil fuels (coal, oil, and natural gas) are the main sources of electrical energy in many places, but they are limited in supply. It is high time to find other renewable sources of energy to cure this issue. This project explores the feasibility of using Peltier modules to generate electricity from steam. The goal of the research is to determine the effectiveness of Peltier modules in converting heat energy from steam into electrical energy and to identify the optimal conditions for maximizing output power. The experiment utilizes theoretical knowledge to formulate the design and prototype to analyze the results. The research also examines the limitations and challenges of using Peltier modules for steam-to-electricity conversion, including the need for high-temperature differentials and the potential for thermal stress and degradation. Overall, the project demonstrates the potential of Peltier modules as a promising technology for steam-based electricity generation and provides insights for future research and development in this area. The findings have important implications for the development of sustainable energy sources and the reduction of greenhouse gas emissions from fossil fuels.

Chapter 1

Introduction

1.1. Introduction

Electricity is essential to modern life and plays a critical role in almost every aspect of daily life. It powers our homes, schools, and workplaces, providing lighting, heating, and cooling. It is used to run appliances, medical equipment, and communication technologies such as computers, phones, and televisions. The widespread availability of electricity has allowed for the development of many modern conveniences and has improved the overall quality of life for people all over the world. In addition, electricity has revolutionized the way we produce and distribute goods and services, making it possible for businesses to operate more efficiently and effectively. In short, electricity is a fundamental necessity of modern society and its importance cannot be overstated.

This project is all about finding a clean source of energy that can produce electricity from waste heat and any heat source. The idea is to use Peltier modules to generate voltage with the Seabeck effect of the Peltier module. Alongside the Peltier modules, a monitoring system will also be designed to monitor multiple Peltier modules.

1.2. Historical Background

Finding an alternative source for generating electricity is not a recent concern. As the traditional method uses sources that are limited on earth it is a matter of great concern to find an alternative source before it's too late. Researchers have come up with some renewable sources of energy to counter this issue. Some of the research that is similar to this thesis is mentioned below-

1.2.1. Earlier Research

1. **<u>Low-cost stove-top thermoelectric generator for regions with unreliable electricity supply:</u>**

R.Y. Nuwayhid a, D.M. Rowe, G. Min have submitted this research work on February of 2003. This system was designed for the regions where during winter it is must to use stoves and electricity becomes an issue. The idea of the system is to use the Peltier modules to generate electricity from the heat produced by the stoves when using them. This will utilize the heat loss to generate electricity [1].

2. **A study on the potential of Peltier in generating electricity using heat loss at engine system:**

The goal of the research work is to design a system with Peltier module which can generate electricity from waste heat produced by different types of engines. The system uses Peltier module in combination with proper heatsink to increase the efficiency from 6% to 12%. The designed system was tested on vehicle engine to produce electricity and store the electrical energy in 12V battery through a highly efficient PWM charging controller [2].

3. **Energy Generation from Peltier Module by Utilizing Heat:**

Darshak Vadhel, Savadas Modhavadiya and Prof. Jaydipsinh Zala published this Study on IRJET on March of 2017. The idea of the designed system is to produce voltage when other sources are not available. This device will produce voltage from any heat source like stove, burning wood etc. The system uses multiple Peltier modules connected in series to increase the voltage. To further increase the voltage the system also uses DC-DC boost converter [3].

1.2.2. Recent Research

1. **Research and Development of Portable Thermoelectric Generator Using Peltier Plates and Waste Heat:**

Mohammad Monirujjaman Khan introduced this project on November of 2020. The main goal of this project is to generate electricity from waste heat. This system uses Peltier module to generate voltage from heat source and the voltage can be used with 5-volt regulator to power general items or a DC-DC boost converter can also be used to step up the voltage and recharge 12V battery. This system is pretty similar to the proposed system [4].

2. **Study of Multi-stage Peltier Module in Generator Mode:**

This is an experimental study on Peltier modules and their performance as an electricity generator when arranged in a cascaded form. Kaloyan Ivanov, Ivaylo Belovski and Anatoliy Aleksandrov published this study on December of 2020. Four Peltier module of different surface area was used in a cascaded formation and tested the performance. The result of the study shows during this cascaded formation the efficiency of the Peltier modules are drastically decreased and it is strongly advised not to use them in cascaded formation [5].

3. **Power Generation Using by Peltier Module:**

Ritesh Siddharth Borkar published This research on 11/04/2022. The main goal of this research was to generate electricity by burning waste material like cow dung, dry paddy fields, dry leaf etc. The idea here is to burn this kind of unwanted materials and produce heat. Then this heat will be converted to electricity using Peltier modules. After that the produced electrical energy will be stored in a battery by recharging it. This energy then can be used to power appliances like LED bulbs [6].

1.2.3. State of the art technology

Peltier modules, also known as thermoelectric generators (TEGs), are solid-state devices that convert temperature differences into electrical energy. These modules consist of two ceramic plates, one of which is doped with a semiconductor material. When a temperature difference is applied across the plates, an electrical current is generated due to the Seebeck effect. Peltier modules are efficient and reliable, making them an attractive option for electricity generation from steam.

Heat transfer is a crucial aspect of electricity generation from steam using Peltier modules. The efficiency of Peltier modules is influenced by the temperature difference across the plates, the rate of heat transfer, and the thermal conductivity of the materials used. Various heat transfer techniques, such as forced convection, natural convection, and radiation, have been explored to optimize the performance of Peltier modules.

System integration is another critical aspect of electricity generation from steam using Peltier modules. The integration of Peltier modules with steam generation systems requires careful design and engineering to ensure optimal performance. Various system integration techniques, such as series and parallel connections, have been explored to improve the efficiency and reliability of Peltier module-based steam power systems. Also, an Arduino based monitoring system is designed to monitor how much voltage is generated in each Peltier module.

1.3. Advantage over Traditional Method

There are several advantages of Peltier-based electricity generation over traditional methods of electricity generation:

Use of Waste Heat: Peltier devices can generate electricity from waste heat, which is a valuable resource that is often underutilized. This makes Peltier-based electricity generation a more sustainable and efficient option compared to traditional methods that rely on burning fossil fuels.

Low Maintenance: Peltier devices have no moving parts and require little to no maintenance, which reduces the cost and time associated with maintaining traditional electricity generation systems.

Quiet Operation: Peltier devices operate silently, making them a more attractive option for applications where noise pollution is a concern.

Compact and Portable: Peltier devices are small and lightweight, making them an ideal option for portable and remote power applications where traditional electricity generation methods may not be practical.

No Emissions: Peltier devices do not emit any pollutants or greenhouse gases, making them a more environmentally friendly option compared to traditional electricity generation methods.

Overall, Peltier-based electricity generation has several advantages over traditional methods, particularly in terms of sustainability, low maintenance, quiet operation, portability, and environmental impact. While there are still some ethical concerns that must be considered, the potential benefits of this technology make it a promising option for the future of electricity generation.

1.4. Objective of this Work

1.4.1. Primary objectives

Here are some primary objectives of this project-

1. Use multiple Peltier modules to produce electricity.
2. Implement power reading system to read the produced voltage.

1.4.2. Secondary Objectives

1. Use different amount of water to monitor amount of voltage produced.
2. Estimate the voltage for further amount of water.
3. Estimate power generation from real power plant.

1.5. Introduction to this Thesis

Electricity generation is a crucial aspect of modern society, playing a vital role in powering homes, businesses, and industries. With the growing demand for energy, the development of new technologies for electricity generation has become increasingly important. The purpose of this project is to examine electricity generation from steam with thermoelectric device and assess their efficiency, feasibility, and impact on the environment. Through a comprehensive analysis, this project will provide insight into the current state of electricity generation and offer recommendations for future developments in the field.

Chapter 2

Project Management

2.1. Introduction

Project management is crucial in ensuring the successful completion of a project within budget, schedule, and scope constraints. It helps to coordinate and direct the efforts towards a goal, track progress, identify and manage risks, and make necessary decisions. In today's fast-paced and ever-changing business environment, project management has become an essential skill for organizations to achieve their objectives and stay competitive.

This section of the thesis paper will go through some crucial management part of the proposed project which includes S.W.O.T Analysis, P.E.S.T Analysis, Time Management, Cost Analysis and Project Lifecycle.

2.2. S.W.O.T Analysis

S.W.O.T (strengths, weaknesses, opportunities, and threats) analysis is a critical factor for a project. This section will go through all the analysis aspects-

2.2.1. Strengths

High Efficiency: Peltier modules are highly efficient in converting heat into electricity, making the system a potentially cost-effective solution for energy generation.

Versatile: Peltier modules can be used to generate electricity from a wide range of heat sources, including waste heat from industrial processes, solar thermal energy, and even body heat.

Eco-Friendly: By harnessing otherwise wasted heat, the system can help reduce greenhouse gas emissions and contribute to a more sustainable energy mix.

2.2.2. Weaknesses

Cost: Peltier modules can be relatively expensive, which could impact the cost-effectiveness of the system.

Maintenance: Peltier modules can be sensitive to temperature changes and may require regular maintenance to ensure optimal performance.

Scalability: Depending on the heat source and the size of the system, scalability may be a challenge, as the amount of electricity generated is proportional to the amount of heat available.

2.2.3. Opportunities

Demand for Renewable Energy: As more consumers and businesses look for sustainable energy solutions, there is increasing demand for renewable energy technologies like this one.

Government Incentives: Governments around the world are offering incentives to businesses that invest in renewable energy, which could make this system more attractive to investors.

Integration with other systems: This system could potentially be integrated with other energy systems, such as solar panels or wind turbines, to provide a more complete and sustainable energy solution.

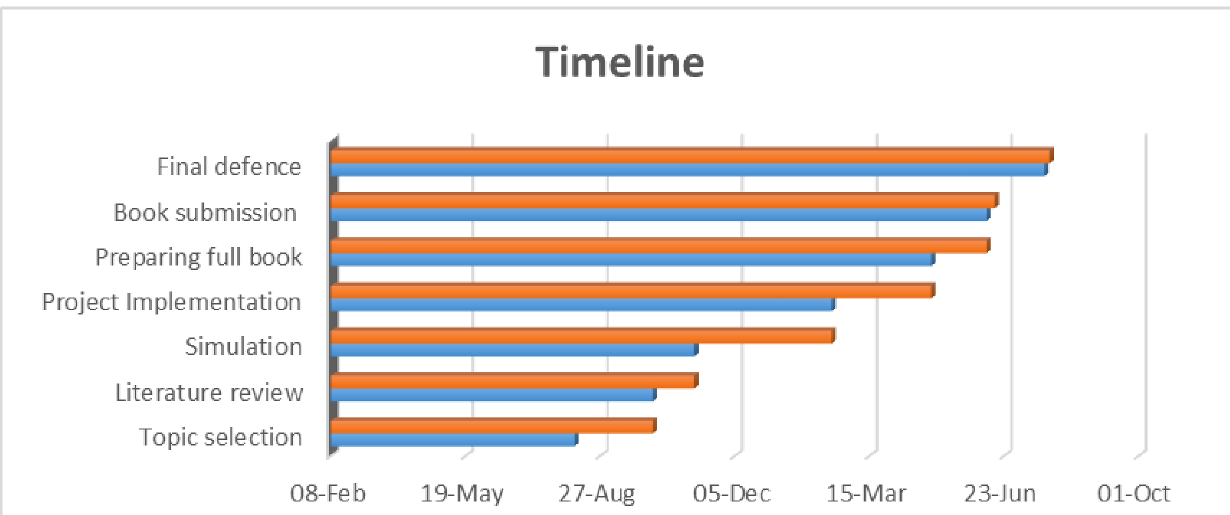
2.2.4. Threats

Competition: There are many other renewable energy technologies available, including solar, wind, and hydro power. This system may face competition from these alternatives, which could impact its success.

Technological advancements: Advances in other renewable energy technologies, or in energy storage solutions, could make this system less attractive to consumers and investors.

Regulatory barriers: Depending on the location, there may be regulatory barriers to implementing this system, such as building codes or zoning regulations, which could impact its viability.

2.3. Schedule Management



	Topic selection	Literature review	Simulation	Project Implementation	Preparing full book	Book submission	Final defence
End date	5-Oct	5-Nov	15-Feb	30-Apr	10-Jun	16-Jun	27-Jul
Start Date	08-Aug	05-Oct	05-Nov	15-Feb	30-Apr	10-Jun	23-Jul

Fig 2.1: Project Timeline (Gantt Chart).

2.4. Cost Analysis

Table 2.1- Cost Table

No	Item	Quantity	Price
01	Arduino Pro mini	1 pc	780/-
02	12V Peltier Module	4 pcs	1480/-
03	16x2 LCD Display	1 pc	380/-
04	I2C Module	1pc	190/-
05	Electric Kettle	1 pc	1090/-
06	Voltage Divider	1 pc	180/-
07	Battery	1 pc	180/-
08	LED	4 pcs	10/-
09	PCB	1 pc	100/-
10	Switch	1 pc	15/-
11	PVC	3 ft	380/-
12	Electric Wire	10 set	200/-
13	Glue Stick	3 pcs	90/-
14	Super Glue	1 pc	30/-
15	Lead	N/A	100/-
16	Other	N/A	500/-
Total Cost			**5705/-**

The cost mentioned in the Table 2.1 may differ in later days due to various external reasons like-

Quantity: The cost of components can often be reduced when purchased in larger quantities. The listed price may be for a single component, but purchasing in bulk may result in a lower unit cost.

Supplier: Different suppliers may offer components at different prices, based on factors such as quality, availability, and shipping costs.

Quality: Components of different quality levels may have different prices, with higher-quality components generally being more expensive.

Availability: If a component is in high demand and low supply, its price may increase due to scarcity.

Market forces: Like any other commodity, component prices can be affected by market forces such as inflation, currency exchange rates, and supply and demand.

2.5. P.E.S.T Analysis

PEST analysis is a framework used to analyze the external macro-environmental factors that can impact a project. PEST stands for Political, Economic, Social, and Technological factors.

2.5.1. Political Factors

Government Regulations: The system may need to comply with various government regulations related to energy generation and usage. Regulations regarding the use of Peltier modules for energy generation may also be relevant.

Tax Incentives: Governments may offer tax incentives for businesses and individuals that invest in renewable energy solutions, which could make this system more attractive.

Trade Policies: International trade policies may impact the availability of Peltier modules, as well as the competitiveness of the system in different markets.

2.5.2. Economic Factors

Energy Prices: The cost-effectiveness of the system may be influenced by fluctuations in energy prices, particularly if the system is used to generate electricity for commercial or industrial purposes.

Interest Rates: The availability of financing for the system may be impacted by interest rates, which could impact the overall cost of the system.

Economic Growth: The overall health of the economy may impact the demand for energy solutions like this one, as well as the willingness of consumers and businesses to invest in such solutions.

2.5.3. Social Factors

Public Opinion: The public perception of renewable energy solutions may impact the demand for this system, particularly if there is a negative perception of Peltier modules or their potential impact on the environment.

Education Levels: The level of technical knowledge about Peltier modules and their potential for energy generation may impact the demand for this system, as well as the willingness of consumers and businesses to invest in the technology.

Population Growth: Population growth may impact the demand for energy solutions like this one, as well as the willingness of consumers and businesses to invest in such solutions.

2.5.4. Technological Factors

Advances in Technology: Advances in other renewable energy technologies, such as solar or wind power, or in energy storage solutions, could impact the competitiveness of this system.

Availability of Peltier Modules: The availability and reliability of Peltier modules may impact the viability of this system, as well as the costs associated with using the technology.

Rate of Technological Change: The rate of technological change may impact the competitiveness of this system, as well as the willingness of consumers and businesses to invest in the technology.

2.6. Project Lifecycle

The lifespan of a Peltier-based electricity generating system depends on various factors such as the quality of materials used, the operating conditions, and the level of maintenance it receives.

Under normal operating conditions and regular maintenance, a well-designed Peltier-based system can last for several years, up to 10 years or more. However, if the system is exposed to high temperatures, humidity, or mechanical stress, its lifespan may be shorter. The primary reason for Peltier module failure is thermomechanical stress. When a Peltier module is subjected to thermal cycling due to changes in temperature, the differential expansion and contraction of the different materials used in the module can create internal stresses that may cause the module to fail over time.

Furthermore, the performance of the Peltier module can also degrade over time due to factors such as thermal fatigue, oxidation, and wear and tear. It's important to use high-quality materials, proper thermal management, and regular maintenance to ensure the optimal lifespan and performance of a Peltier module.

2.7. Summary

In conclusion to this chapter, this chapter has gone through S.W.O.T analysis, P.E.S.T analysis, Cost analysis with cost table, schedule management of the project with proper Gantt chart, and project lifecycle. The upcoming chapter will go through the block diagram and implementation of the system. Parts used in the system with proper description and specification.

Chapter 3

Project Implementation

3.1. Introduction

Project implementation involves the actual execution of the plan to achieve the goals and objectives outlined in the project plan. This section will elaborately go through the procedure of implementing the system. This chapter includes methodology which describes how the electricity is generated with Peltier module and block diagram of the full system, description of the used components and designed hardware of the full system.

3.2. Methodology

For the proposed system the heart of the system is the Peltier module. This is also known as thermo electric device as the main work of this module is to convert the electrical energy into head and this module can also work the other way around.

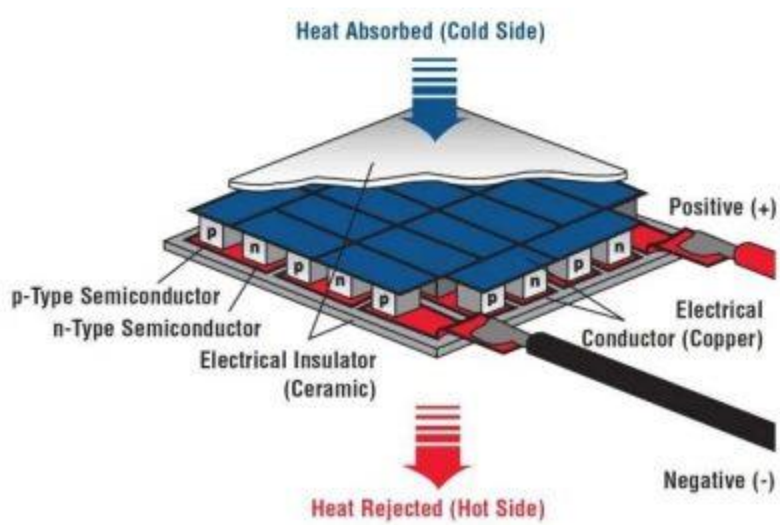


Fig 3.1: Thermoelectric Device (Peltier) [7].

A Peltier module, also known as a thermoelectric module, is a solid-state device that uses the Peltier effect to transfer heat from one side of the device to the other. The Peltier effect occurs when electrical current flows through two different types of conductive materials, causing heat to be absorbed or released at the junction of the two materials. These materials can be combination of constantan and copper, constantan and iron, constantan and chromel, constantan and alumel. When voltage is applied to a Peltier module, it causes a flow of electrons, which results in the transfer of heat from one side of the module to the other. The direction of heat transfer can be reversed by reversing the direction of the electrical current.

Though this is the main type of use for this kind of module, in this system the opposite characteristic of this kind of module is used which is known as Seebeck effect. The Seebeck effect, also known as the thermoelectric effect, is a phenomenon that occurs when a temperature difference is applied across a material, causing a flow of electrical current. The Seebeck effect is the basis for the operation of thermoelectric generators, which convert heat energy into electrical energy. The Seebeck effect is proportional to the temperature difference and the material's thermopower, which is a property that describes the ability of a material to convert heat into electricity. The thermopower depends on the material's electrical and thermal conductivity, as well as its density of states.

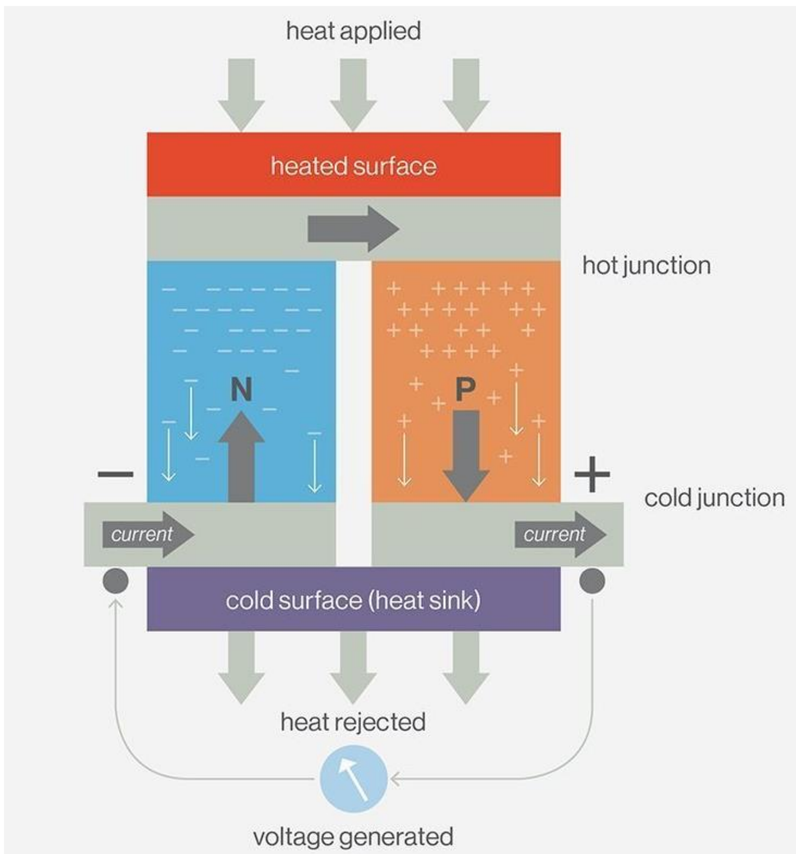


Fig 3.2: Seebeck Effect of Semiconductor [8].

The Seebeck coefficient, or thermopower, is a measure of a material's ability to convert heat into electrical energy and is given by the formula:

$S = (\Delta V / \Delta T) * (1 / T)$ ---(1)

where S is the Seebeck coefficient, ΔV is the voltage generated, ΔT is the temperature difference across the material, and T is the temperature in kelvins.

The electrical power generated by a thermoelectric device can be calculated using the formula:

$P = S * \Delta T * A$ --(2)

where P is the electrical power, A is the cross-sectional area of the device, and ΔT is the temperature difference across the device.

The efficiency of a thermoelectric device can be calculated using the formula:

$\eta = P / Q$ ---(3)

where η is the efficiency, P is the electrical power generated, and Q is the heat flow into the hot side of the device.

These formulas are based on the basic principles of the Seebeck effect and provide a good starting point for understanding how thermoelectric devices work. However, it is important to note that in real-world applications, there are many factors that can affect the performance of a thermoelectric device, including the size and geometry of the device, the materials used, and the temperature difference across the device.

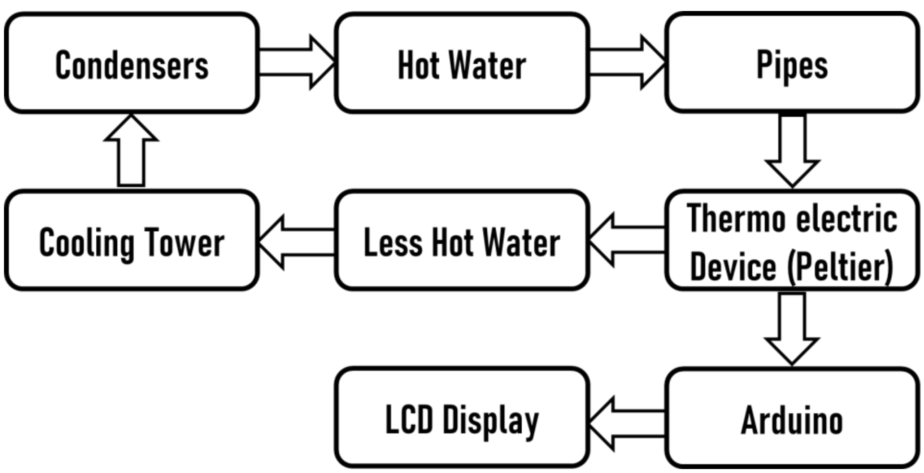


Fig 3.3: Block diagram of Full System.

Fig 3.3 shows the full block diagram of the proposed system. The main idea here is to make a system that takes boiling water and passes the steam through a path which is connected to multiple Peltier module which will produce voltage due to previously mentioned Seebeck effect. Output of all these Peltier modules will be connected to the Arduino microcontroller which will measure the produced voltage and show the value on the LCD display.

3.3. Used Components

There are several major components used in the designed system. The list is-

- 16x2 LCD Display
- I2C LCD Interface Module
- Arduino Pro Mini
- Peltier Module (Thermoelectric Device)
- Water Kettle

Details of some components and use in the system has described below.

3.3.1. Arduino Pro Mini

Fig 3.4: Arduino Pro Mini [9].

Arduino Pro Mini is a microcontroller based on the ATmega328p chip which is designed by the Arduino corporation. This is a compact model of the Arduino Uno with same functionalities and specification other than there is no direct USB to TTL converter which means it requires another USB to serial converter to upload codes to its processor. This will work as the brain of the system and measure the output voltage from all the Peltier modules and output the data on the LCD display. Some main specification of the microcontroller is shown below [9]-

Microcontroller	ATmega328P
Board Power Supply	3.35 -12 V (3.3V model) or 5 - 12 V (5V model)
Circuit Operating Voltage	3.3V or 5V (depending on model)
DC Current per I/O Pin	40 mA
Flash Memory	32KB of which 2 KB used by bootloader
Clock Speed	8 MHz (3.3V versions) or 16 MHz (5V versions)

3.3.2. 16x2 LCD Display

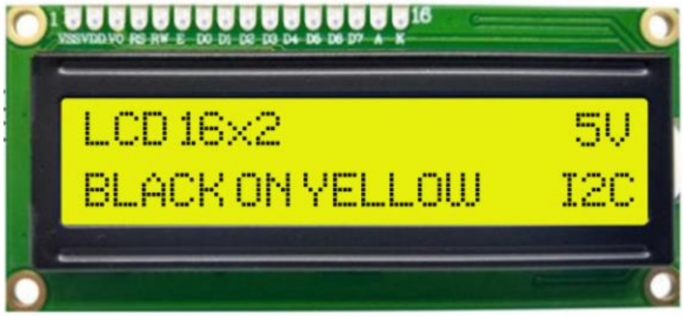


Fig 3.5: 16x2 LCD Display Module [10].

As the name implies the display is divided into 16 columns and 2 rows which implies the display can show 32 characters at once. Each segment is comprised of several pixels. This type of display is commonly used with Arduino to view output data. The display has several models based on color. The module uses 5V to operate. Other than power and ground cable the display requires 6 communication lines to work with Arduino. To minimize this data lines I2C modules are used.

3.3.3. I2C Interface Module

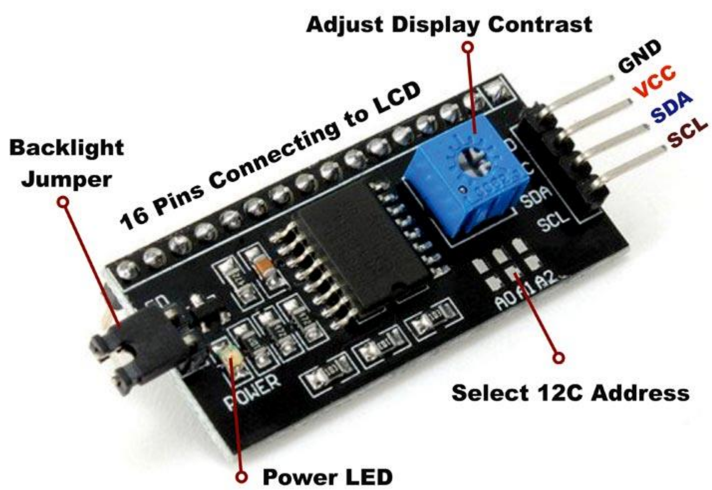


Fig 3.6: I2C Adapter Pinout [11].

Controlling an LCD panel could be challenging due to a microcontroller/constrained microprocessor's pin resources. The process is made simple with just two pins by serial to parallel adapters like the I2C serial interface adapter module with PCF8574 chip. A 16x2 LCD can be linked to the serial interface adapter, which also offers two signal output pins (SDA and SCL) that can be used to connect to a microcontroller in this project which is the Arduino pro mini.

3.3.4. Thermoelectric Device (Peltier Module)

Fig 3.7: Peltier Module [12].

This the main element of the whole system. Peltier module will generate electricity using hot steam. Several models of Peltier module are available in the market. This type of Peltier modules can handle temperature ranges from 100 – 200 C. Some are [13]-

1. High-Performance
2. High-Temperature
3. Micro
4. Multi-Stage
5. Series-Parallel
6. Standard

The Peltier module is available in different operating voltage and power consumption stating from 5V. The most common module available in the market is the 12V 60W module. Several of these modules are used in the system to produce electricity.

3.3.5. Water Kettle (Steam Source)

Fig 3.8: Electrical Water Kettle [14].

Electric kettle was used to simulate controlled steam generator. This kettle uses electricity to boil water and in the project this steam is used to generate electricity with the Peltier modules. This type of kettle is available in the market in various design and power consumption. The higher the consumption of power the faster the water will boil.

3.4. Designed System

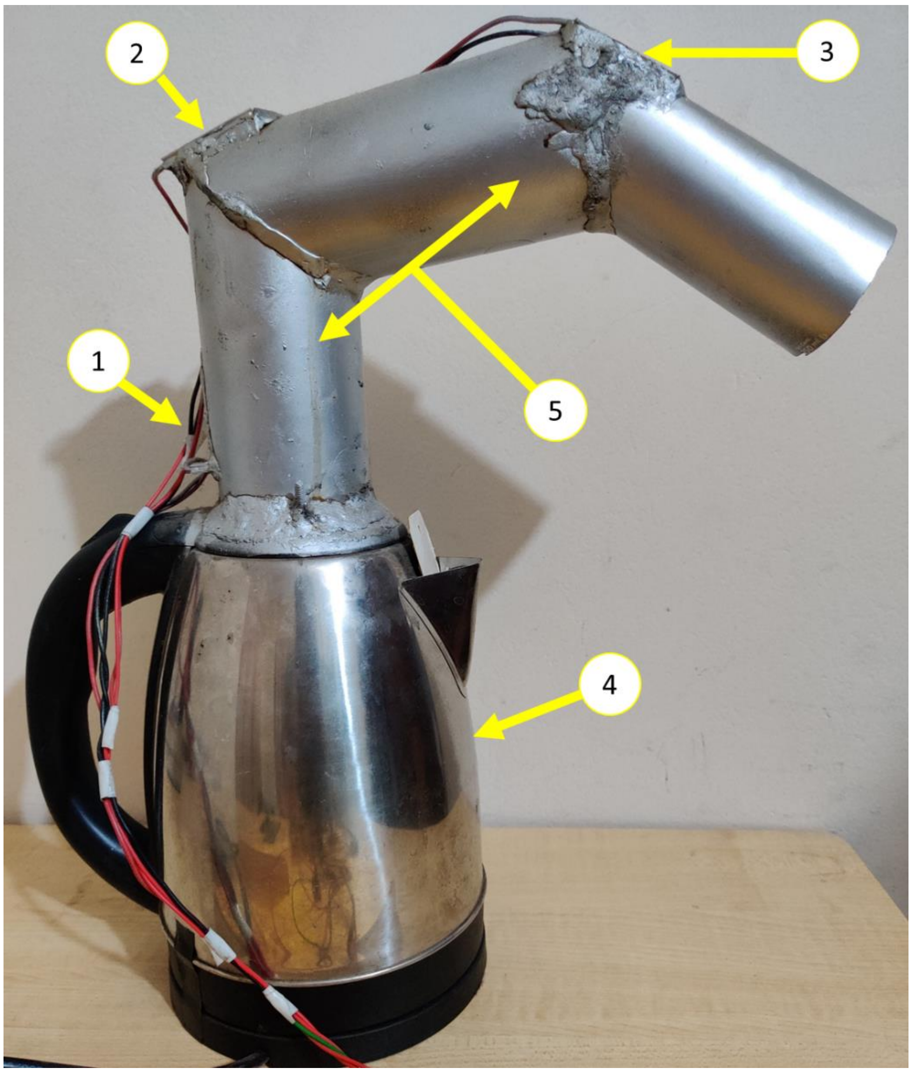


Fig 3.9: Steam Generator and Peltier Modules.

The Fig 3.9 shows the water kettle in this project the steam generator marked as number 4. Number 5 marked in the image is the steam pine by which the steam passes through all the Peltier modules. Three Peltier modules are position in the marked 1,2,3 marked on the steam pipe. Wires shown in the image carries the produced power to the controlling unit and the Arduino based system reads the data and outputs the value from all the modules to the LCD display.

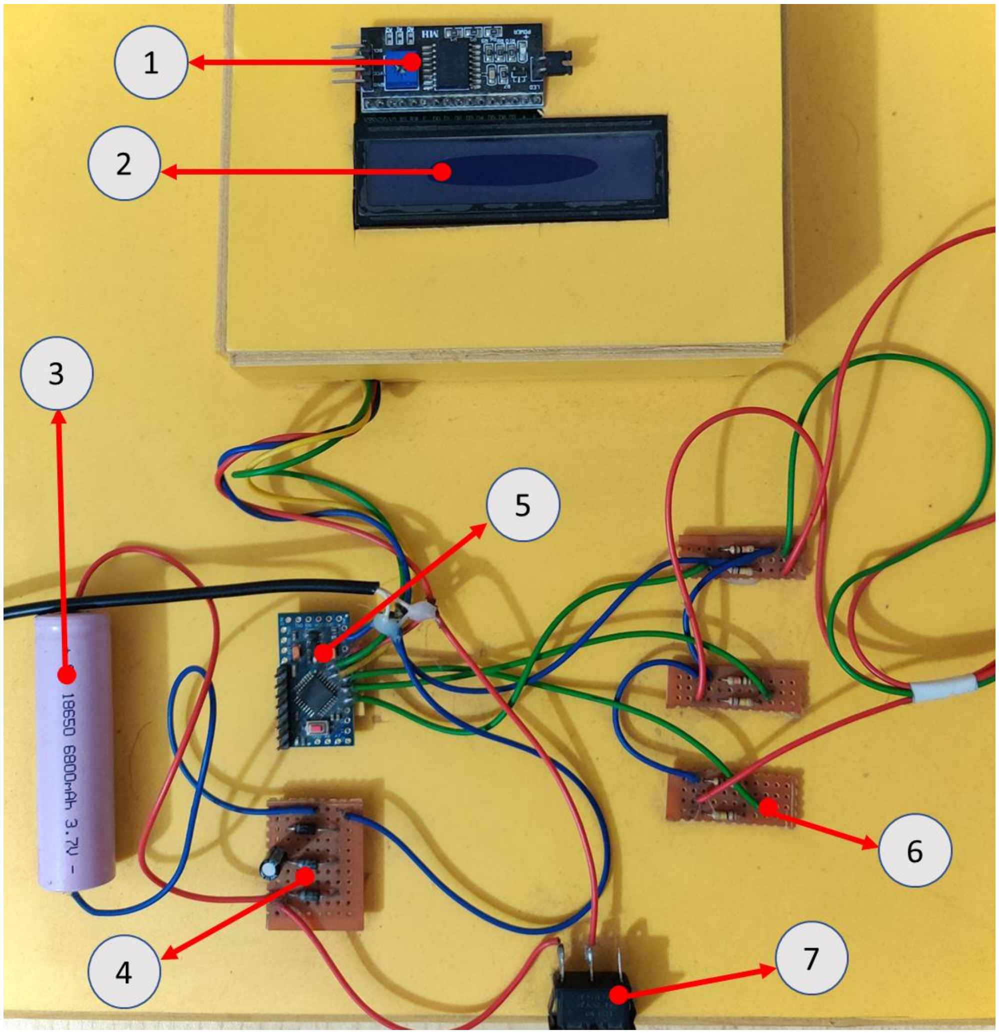


Fig 3.10: Implemented Monitoring System.

In the figure 3.10 the designed monitoring system can be seen with all its components. The marked components are-

1. I2C Module
2. 16x2 LCD Display
3. Rechargeable Battery
4. Battery Power Management System
5. Arduino Pro Mini
6. Voltage Divider
7. Switch

The working procedure for this system starts from the Peltier modules. Produced voltage connects to 3 different voltage divider which lowers the voltage to a suitable range for the Arduino to read. Analog input pin A0, A1, and A2 is used as the input pin to read the voltage levels. After calculating the voltage with respect to the voltage deliver the measured voltage then display signal is sent to the I2C module which helps to display the value in the LCD properly. there is also a battery which is charged through the power management system with the voltage generated form the Peltier module. This battery works as the load and also as the backup power source when the Peltier modules cannot provide enough voltage.

3.5. Summary

This section of the thesis book has gone through the method of implementation if the proposed system including block diagram, description of parts and their use. Hardware parts are also shown in this section of the book. The implementation was done properly and everything was running properly but effectiveness of the system will be tested and outcomes will be analyzed in the upcoming section. The section will also include description of the code result graphs.

Chapter 4

Result Analysis

4.1. Introduction

Result analysis refers to the process of examining and interpreting the outcomes of a particular activity or event in this case the designed system. The goal of result analysis is to gain insight into the underlying factors that contribute to the outcome and identify areas for improvement or optimization. This involves comparing the results against past performance, industry benchmarks, or other relevant criteria. After going through all the implementation and designing method this section of the book covers the outcome of the system. How the system worked in real life and how much electricity it was capable of generating will also be gone through.

4.2. Hardware Results

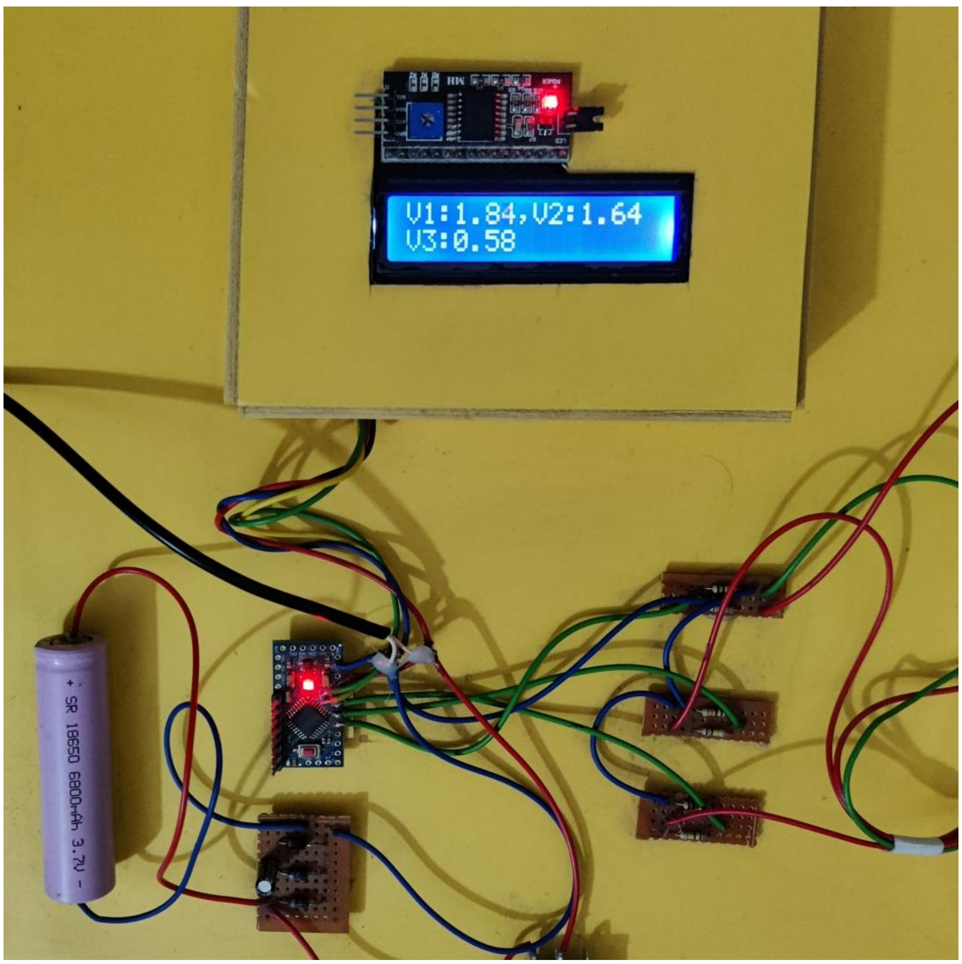


Fig 4.1: The Implemented System While Running.

In the Fig 4.1 the running system can be seen. The LCD can be seen showing 3 different voltage value labeled V1, V2, and V3 which are the voltage recorded from the Peltier modules. The system is fully running on the voltage produced by the Peltier modules and also the battery is being charged from the modules. There isn't anything complicated in this monitoring system. The system was tested three times with different amount of water in the boiling kettle and the collected data can be seen below-

Fig 4.2: Voltage With 100ml Water.

Testing the system with 100ml water produces voltage of-

V1	V2	V3
1.84V	1.64V	0.58V

Fig 4.3: Voltage With 250ml Water.

Testing the system with 250ml water produces voltage of-

V1	V2	V3
2.32V	1.93V	0.68V

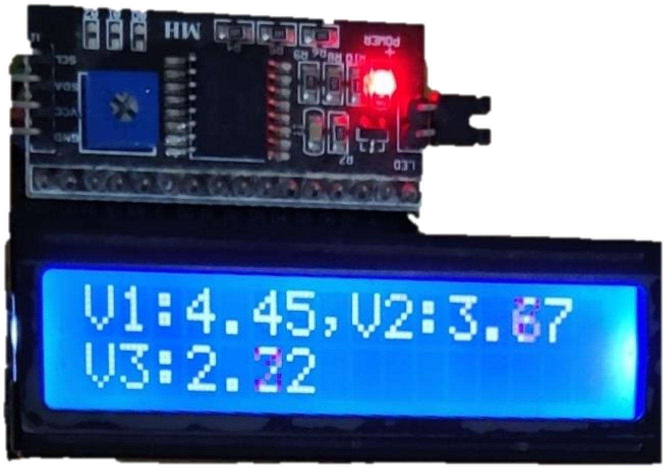


Fig 4.4: Voltage With 500ml Water.

Testing the system with 500ml water produces voltage of-

V1	V2	V3
4.45V	3.67V	2.22V

Fig 4.5: Voltage With 750ml Water.

Testing the system with 750ml water produces voltage of-

V1	V2	V3
5.22V	4.64V	3.09V

This data will be further analyzed in the upcoming section of this thesis paper.

The current output of the Peltier modules can be measured by a multimeter as shown below-

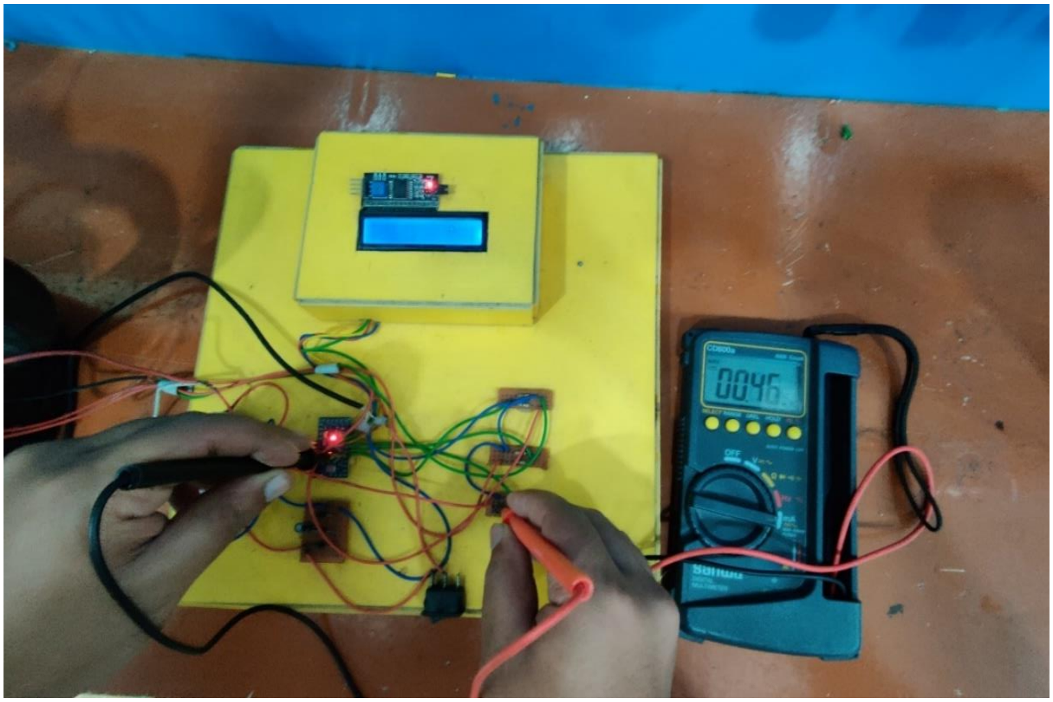


Fig 4.6: Current Reading with 100ml Water.

In figure 4.6, when using 100 ml of water the system was shown output 0.46 mA of current. At last, the output current was 10.2 mA for peltier 1, 8.9mA for peltier 2 and 3.1mA for peltier 3.

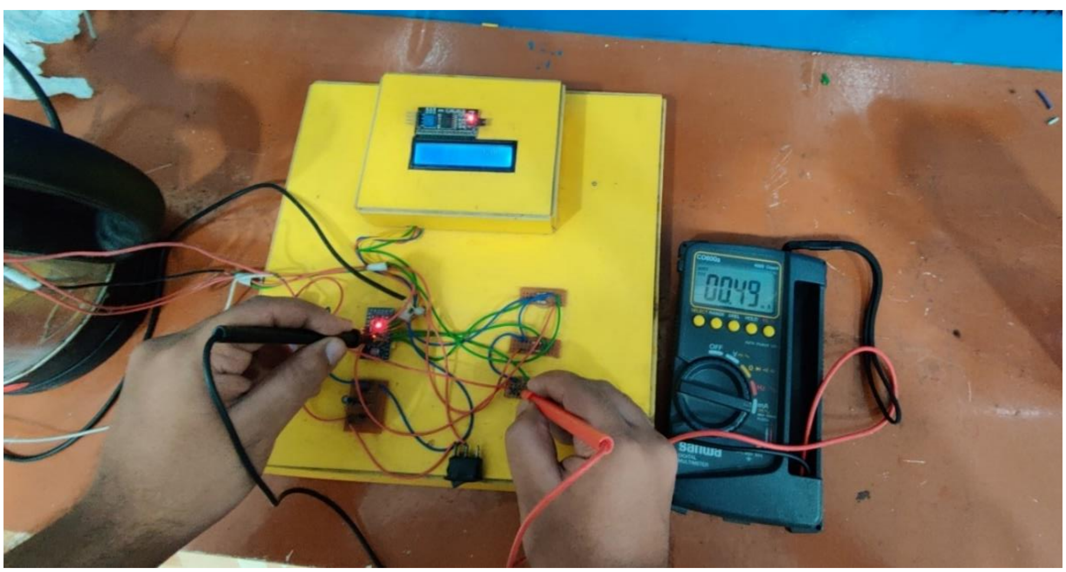


Fig 4.7: Current Reading With 250ml Water.

Using 250ml water the system was shown output around 0.49mA of current which can be seen in Fig 4.7. At the end the highest output was 24.7mA for peltier 1, 20.54mA for peltier 2 and 7.6mA for peltier 3.

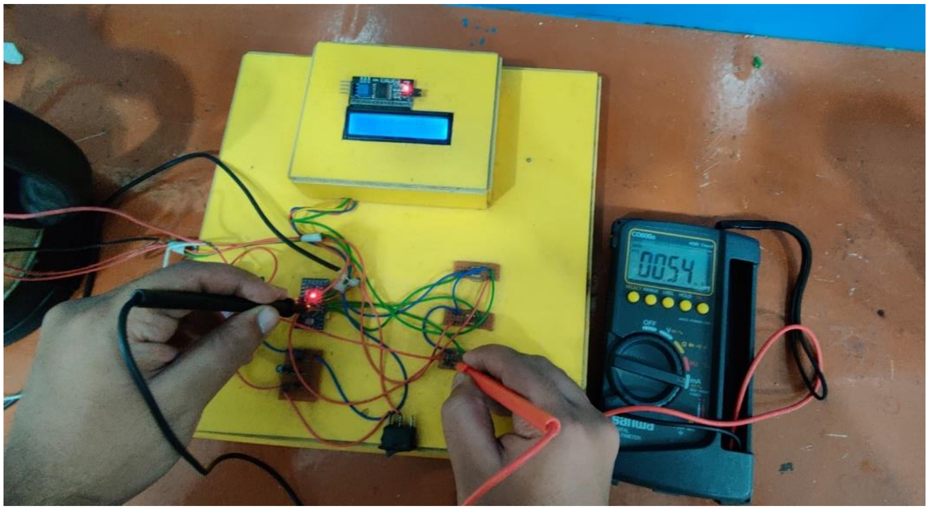


Fig 4.8: Current Reading with 500ml Water.

Using 500ml Water the system can produce a total current of 0.54mA which increases as the modules properly heats up. The data reading can be seen in Fig 4.8. At last, the output current was 51.1mA for peltier 1, 42.3mA for peltier 2 and 25.6mA for peltier 3.

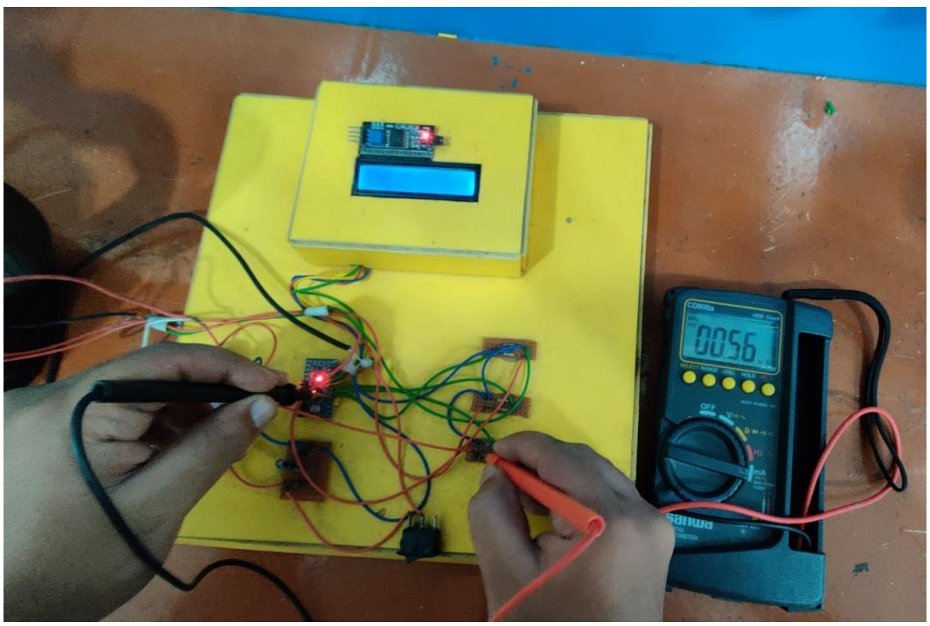


Fig 4.9: Current Reading with 750ml Water.

As per previous reading, with 750ml water the system initially outputs current of 0.56mA which increases as the system runs for further amount of time. At last, the output current was 72.2mA for peltier 1, 64.3mA for peltier 2 and 42.74mA for peltier 3.

4.3. Output Data Analysis

After collecting data from the Peltier modules with different amounts of water. All the recorded data can be seen in the table below.

Table 4.1: Voltage and current Reading for Peltier Modules

Water (ml)	V1 (Volt)	Current (mA)	V2 (Volt)	Current (mA)	V3 (Volt)	Current (mA)
100	1.84	10.2	1.64	8.9	0.58	3.1
250	2.32	24.7	1.93	20.54	0.68	7.6
500	4.45	51.1	3.67	42.1	2.22	25.6
750	5.22	72.2	4.64	64.3	3.09	42.74

From the data gathered in the previous table we can calculate the Power output of each Peltier module. In this case the load is the voltage divider circuit with two resistors with values of 100k and 10k ohm. The power is calculated with formula P=V x I. From the calculated power value, the energy can be calculated per hour. As the test was run for about 15 min., we can calculate the energy per hour by the formula of Energy = (V×I×min)/60 The result will be in Wh. The below table shows the calculated data.

Table 4.2: Power Calculation of Peltier Modules

Water (ml)	P1 (mW)	Energy (mWh)	P2 (mWh)	Energy (mWh)	P3 (mWh)	Energy (mWh)
100	18.768	4.692	14.596	3.649	1.798	0.4495
250	57.304	14.326	39.6422	9.91055	5.168	1.292
500	227.395	56.84875	154.507	38.62675	56.832	14.208
750	376.884	94.221	298.352	74.588	132.0666	33.01665

From the calculated data it is possible to estimate the amount of water required to generate energy of 100MW. Using 750 ml water we can generate a total of 201.8256mWh of energy from 3 Peltier module. So, 750-liter water is required to generate 201.8256mWh of energy combined with 3 Peltier module.

4.3.1. Case Study

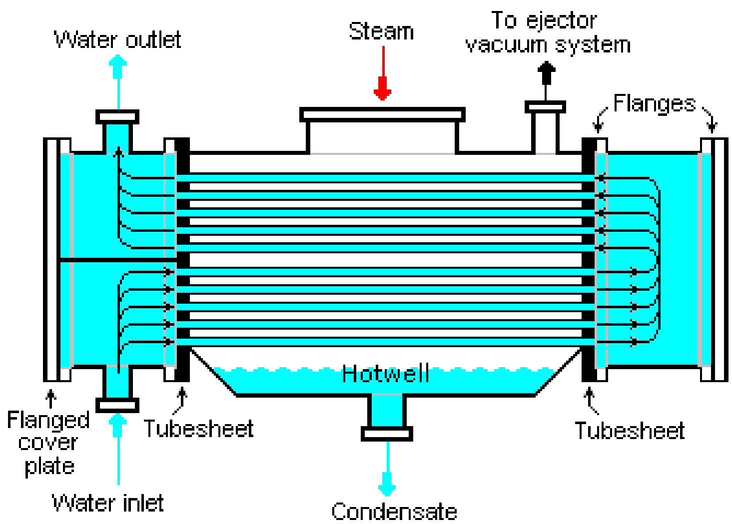


Fig 4.10: Condenser of Steam Power Plant [16].

The Aowrahati 100 MW Diesel Power Plant, often referred to as the Aowrahati Fast Tract Power Plant, is a reciprocating engine-based power plant located in the Bangladeshi district of Dhaka's Aowrahati inside Keraniganj Upazila [15]. From Aowrahati 100 MW (Aggreko) HSD Power Plant [15], I got that approximately 13 tons of steam is required for a 100Mw power plant per hour. To calculate the energy produced by 13 tons of steam, we can use the given information and conversion factors.

First, let's convert 13 tons to milliliters.

1 ton = 1000000 grams

1 gram of water = 1 milliliter

13 tons = 13 * 1000000 = 13,000,000 grams

13,000,000 grams = 13,000,000 milliliters

Now, we know that 750 ml of steam can generate 201.8256mWh of energy from 3 Peltier module. To find out how much energy 13,000,000 ml of steam can produce, we can set up a proportion:

Energy produced by 13,000,000 ml = (Energy produced by 750 ml * 13,000,000) / 750

Energy produced by 13,000,000 ml = (201.8256 * 13,000,000) / 750

Energy produced by 13,000,000 ml = 3,508,587.2mWh of energy = 3.5 units of energy

So, 13 tons of steam can produce approximately 3.5 units of energy from 3 Peltier module.

This power plant condenser has approximately 12 pipes, and each pipe has a length of 5.5-meter total, a total number of 300 to 400 Peltier modules can be placed in between them. As from the calculation above we got approximately 3.5 units of energy using 3 Peltier modules. So, energy output of 400 Peltier modules can be calculated by-

$$\text{Total Energy} = 400 \text{ x } \frac{3.5}{3} = 466.67 \text{ unit}$$

With all the data from Table 4.1 a graph can be plotted to better represent the data.

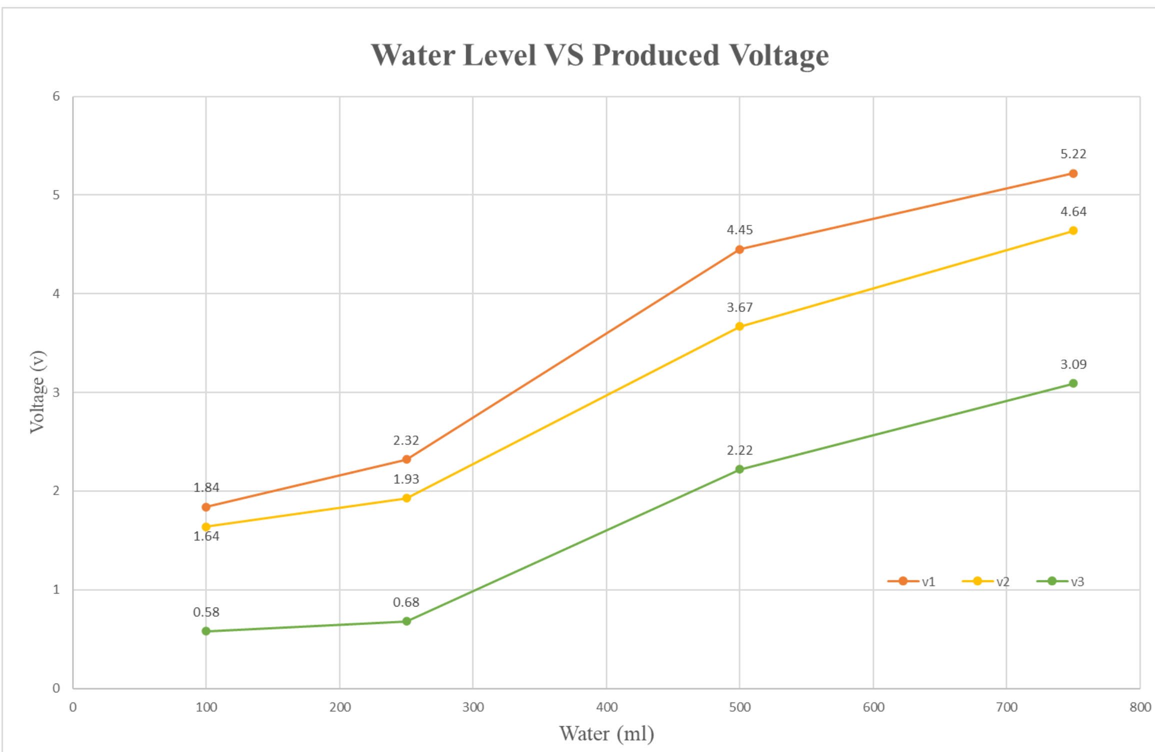


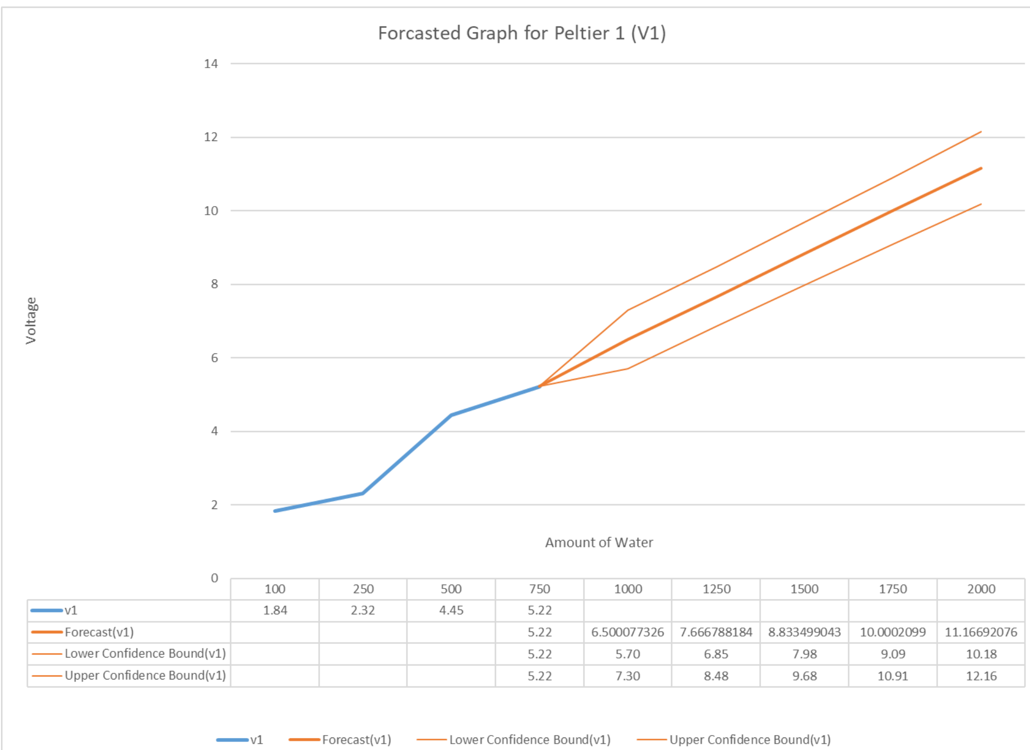
Fig 4.11: Water VS Voltage Graph.

The graph shown in Fig 4.11 can describe the whole system. In the graph the red line represents voltage produced in the Peltier 1 which is closest to the heat source. After that the Peltier 2 is drawn in yellow graph and it is in the middle of three Peltier modules. And lastly the third Peltier output is drawn with green light and is the furthest from the heat source. The position of the Peltier modules can be estimated by looking at the graph. The first Peltier module produces the most amount of voltage as it is the closest to the heat source.

As the steam passes it loses its amount of heat, that's why by the time the steam reaches the second Peltier it doesn't have the same amount of heat so the second Peltier cannot produce a similar amount of voltage as the first one. Similarly, by the time steam reaches the third Peltier module it loses more heat and the third produces the least amount of voltage.

The amount of water also affects the voltage produced in the Peltier modules. When using the least amount of water, the water cannot produce much steam to push the Peltier modules to produce much voltage. When the amount of water is increased the steam is produced for longer amount of time and this helps the Peltier modules to generate higher voltage as the voltage in the Peltier module increases gradually. Thus, when using the most amount of water, the Peltier modules can produce the most amount of voltage during testing. This gradual increase in voltage are not infinite. The Peltier modules will get saturated after getting to their rated voltage which means they cannot produce voltage beyond their own rated voltage.

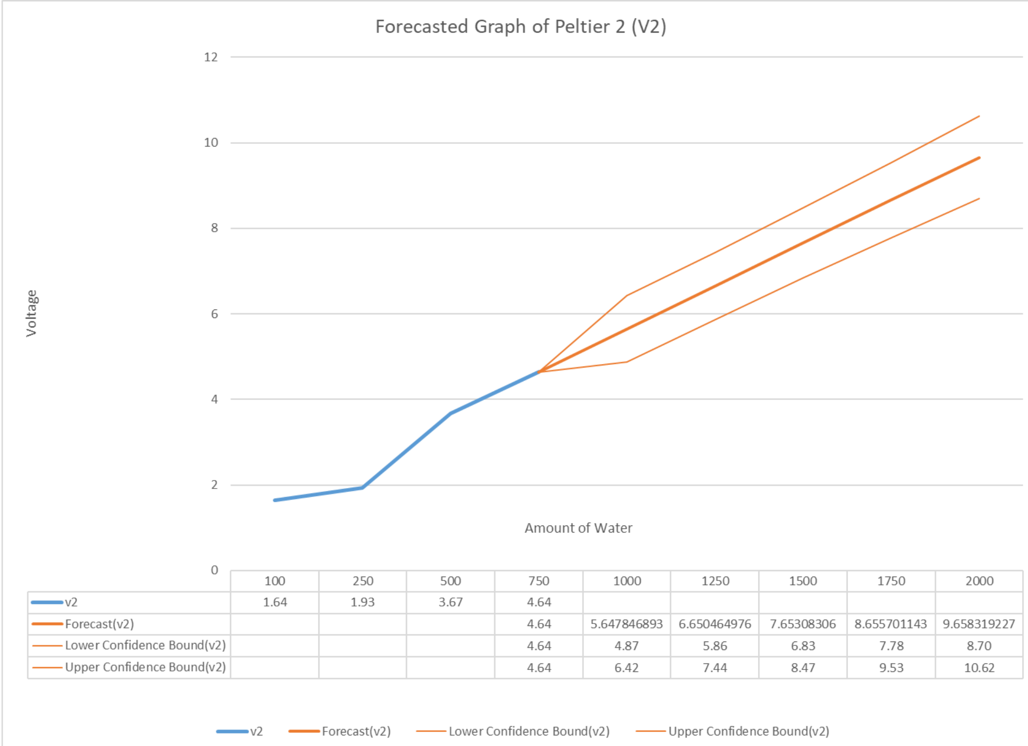
It is possible to feed the data to the excel system which can then process and analyze the data to make an estimation and forecast the graph.



	100	250	500	750	1000	1250	1500	1750	2000
v1	1.84	2.32	4.45	5.22					
Forecast(v1)				5.22	6.500077326	7.666788184	8.833499043	10.0002099	11.16692076
Lower Confidence Bound(v1)				5.22	5.70	6.85	7.98	9.09	10.18
Upper Confidence Bound(v1)				5.22	7.30	8.48	9.68	10.91	12.16

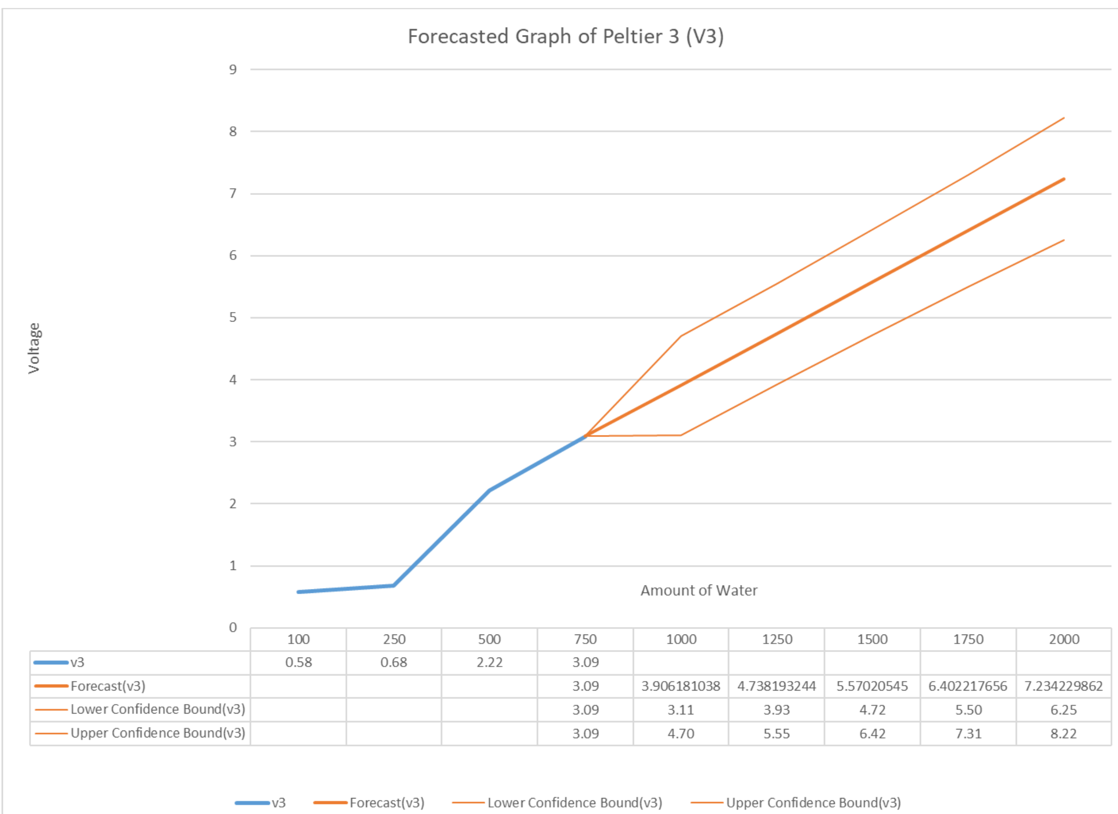
Fig 4.12: Forecasted Voltage Generation of Peltier 1.

The Fig 4.12 shows the estimated produced voltage in the Peltier module 1 with higher amount of water. As a 12V Peltier module was used in the designed system the output voltage of the system cannot go beyond 12V.



	100	250	500	750	1000	1250	1500	1750	2000
v2	1.64	1.93	3.67	4.64					
Forecast(v2)				4.64	5.647846893	6.650464976	7.65308306	8.655701143	9.658319227
Lower Confidence Bound(v2)				4.64	4.87	5.86	6.83	7.78	8.70
Upper Confidence Bound(v2)				4.64	6.42	7.44	8.47	9.53	10.62

Fig 4.13: Forecasted Voltage Generation of Peltier 2.



	100	250	500	750	1000	1250	1500	1750	2000
v3	0.58	0.68	2.22	3.09					
Forecast(v3)				3.09	3.906181038	4.738193244	5.57020545	6.402217656	7.234229862
Lower Confidence Bound(v3)				3.09	3.11	3.93	4.72	5.50	6.25
Upper Confidence Bound(v3)				3.09	4.70	5.55	6.42	7.31	8.22

Fig 4.14: Forecasted Voltage Generation of Peltier 3.

Similarly, output voltage of the Peltier module 2 and 3 can be estimated as shown in the Fig 4.13 and Fig 4.14 with the help of excel for further amount of water. All the graphs have limitations of operating voltage of the Peltier modules means the produced voltage cannot go beyond the operating voltage of the Peltier modules which is 12V. Also, in the graph the increment of the voltage is calculated linear which may not be practical as external factors like heat transportation, ambient temperature, heat sink etc. may affect the produced voltage in the Peltier modules as seen in the Fig 4.11.

From the analysis of the data obtained from the Peltier modules it can be said that the Peltier modules are producing voltage as they should. So, the designed system is a success.

4.4. Summary

This chapter has gone through the results of the designed system. This chapter presented different amounts of voltage generated from different amounts of water, graphs to represent the data better and data analysis. In conclusion it can clearly be said that the system works properly. in the upcoming chapter some limitations, future scopes, ethical concerns, novelty of the work etc. will be presented.

Chapter 5

Discussions and Conclusions

5.1. Discussions

This project represents a comprehensive investigation into the exciting possibility of harnessing electricity from Peltier modules by utilizing steam as the heat source. The study has yielded promising results, indicating that Peltier modules can effectively generate electricity from steam, thus opening up a pathway towards a sustainable and eco-friendly source of power generation in the future. The implications of these findings are significant and have the potential to revolutionize the renewable energy landscape.

One of the key insights from this research is the validation of Peltier modules as a renewable energy source. These modules can be seamlessly integrated into existing thermal power plants or other heat sources, enabling a more efficient and eco-conscious electricity generation process. By utilizing this technology, we have the power to curb carbon emissions and advance towards a greener and cleaner energy future.
The designed system, which converts steam into electricity through Peltier modules, has shown remarkable success in the empirical tests. As presented in the previous section of this thesis, the system effectively produced power from steam. The concurrent implementation of an Arduino microcontroller for monitoring and measuring the voltage output from the Peltier modules further strengthens the credibility of the proposed approach.

In summary, the project's outcomes firmly establish electricity generation from Peltier modules using steam as a promising technology with substantial potential. The integration of these modules with steam as a heat source could play a pivotal role in transforming the energy landscape, making it more sustainable and economically viable. The positive results obtained from this study set the stage for future research, which should concentrate on enhancing the efficiency and scalability of this technology to make it even more competitive and widely adopted within the renewable energy market.

In conclusion, the prospect of generating electricity from Peltier modules using steam represents an exciting and promising frontier in the quest for sustainable energy solutions. This research serves as a significant step forward in realizing the potential of this technology, offering a brighter and cleaner future for power generation.

5.2. Suggestions for Future Work

The designed system has several novelty aspects. One novelty of a Peltier-based electricity generation project could be the use of a unique or unconventional heat source. For example, the project could generate electricity from the heat produced by a wood-burning stove, a car engine, or a solar panel. By using a heat source that is not commonly used for electricity generation, the project could demonstrate a novel application of Peltier technology.

A Peltier-based electricity generation project could also be novel in the way it integrates with other technologies. For example, the project could combine a Peltier module with a battery system or a solar panel to create a hybrid energy system. By combining multiple technologies, the project could demonstrate a novel approach to energy generation and storage.

Finally, a novelty of a Peltier-based electricity generation project could be its portability or off-grid application. Because Peltier modules can generate electricity from low-grade heat sources, a project could be designed to operate in remote or off-grid locations. For example, the project could power a camping stove or a small electronics device in a remote location, demonstrating a novel application of Peltier technology for portable energy generation. Though the system worked properly it surely has some aspects that can be improved further. Some of the aspects are-

1. **Adding Heat sink to the Peltier Modules:** As the amount of voltage generated in a Peltier module depends on the temperature difference of both sides. To maximize the output voltage a heatsink can be added to the cold side of the Peltier module to keep the temperature difference constant. This can make sure that the Peltier module can output a constant voltage.
2. **Using multiple Peltier modules:** Though the designed system uses three Peltier modules to generate electricity, a few more can also be added to make sure the output is maximized.
3. **Using Voltage Regulators:** From the result analysis of the system, it can be noted that the output voltage of the Peltier modules is not constant. It varies time to time depending external condition. To improve this output DC-DC buck boost converters can be used to get a constant voltage output from the system.

5.3. Conclusions

In conclusion, the Peltier-based electricity generator is a promising technology that has the potential to generate electricity from waste heat sources. While there are several benefits to using this technology, such as its low maintenance requirements and ability to operate in remote locations, there are also several ethical concerns that must be considered. These concerns include the environmental impact of manufacturing and disposing of Peltier devices, social justice issues related to the sourcing of rare materials, energy efficiency, cost, and the availability of alternative energy sources. To maximize the benefits of Peltier-based electricity generation and minimize ethical concerns, it is important to prioritize sustainability and consider the broader impacts of using this technology. This may involve developing more efficient Peltier devices, improving the sustainability of materials sourcing and disposal, and exploring alternative energy sources.

Overall, the Peltier-based electricity generator represents a valuable technology for generating electricity from waste heat, but it is important to carefully consider its ethical implications in order to ensure that its use aligns with broader sustainability goals.

REFERENCES

[1] R. Y. Nuwayhid, D. M. Rowe, and G. Min, ("Low-cost stove-top thermoelectric generator for regions with unreliable electricity supply," Renewable energy, 28(2), pp. 205–222. doi: 10.1016/s0960-1481(02)00024-1. (2003)

[2] N. Shalsam, M. H. Harun, M. Yahaya, M. A. Khalil, M. AB. Halim, "A Study on The Potential of Peltier in Generating Electricity Using Heat Loss at Engine System". 10.13140/RG.2.1.2098.0882. (2016)

[3] D. Vadhel, S. Modhavadiya and J. Zala, "Energy Generation from Peltier Module by Utilizing Heat". International Research Journal of Engineering and Technology (IRJET), India. (2017)

[4] Dr. M. Khan, 'Research and development of portable thermoelectric generator using Peltier plates and waste heat', Proceedings of 1st International Electronic Conference on Applied Sciences [Preprint]. doi:10.3390/asec2020-08552. (2020)

[5] K. Ivanov, I. Belovski and A. Aleksandrov, "Study of Multi-stage Peltier Module in Generator Mode," in 2020 7th International Conference on Energy Efficiency and Agricultural Engineering (EE&AE). IEEE, pp. 1–4. (2020)

[6] Mr. A. Halmare, et al. 'Power genration using by peltier module', International Journal for Research in Applied Science and Engineering Technology, 10(4), pp. 2099–2101. doi:10.22214/ijraset.2022.41392. (2022)

[7] N. Dubey, "Top 5 thermoelectric peltier modules manufacturers in the world, Bisinfotech". Available at: https://www.bisinfotech.com/top-5-thermoelectric-peltier-modules-manufacturers-in-the-world/ (Accessed: 31 July 2023). (2022)

[8] R. Awati, "Seebeck effect, Networking. TechTarget". Available at: https://www.techtarget.com/searchnetworking/definition/Seebeck-effect (Accessed: March 29, 2023). (2021)

[9] "Arduino Pro Mini (no date) Arduino.cc". Available at: https://docs.arduino.cc/retired/boards/arduino-pro-mini (Accessed: March 29, 2023).

[10] "LCD 16X2 Black on Yellow I2C - micro robotics (no date) Org.za". Available at: https://www.robotics.org.za/LCD1602-BY-I2C (Accessed: March 29, 2023).

[11] "I2C serial interface adapter module for LCD (no date) Components101". Available at: https://components101.com/modules/i2c-serial-interface-adapter-module (Accessed: March 29, 2023).

[12] "How do thermoelectric coolers (TEC) work (no date) Ii-vi.com?" Available at: https://ii-vi.com/how_do_thermoelectric_coolers_tec_work/ (Accessed: March 29, 2023).

[13] "Peltier - thermoelectric cooler modules - TE tech products (2013) TE Technology". Available at: https://tetech.com/peltier-thermoelectric-cooler-modules/ (Accessed: March 29, 2023).

[14] "Wk-ljss120 (no date) Waltonbd.com." Available at: https://waltonbd.com/kettle-electric/wk-ljss120-en (Accessed: March 29, 2023).

[15] "Aowrahati 100 MW (Aggreko) HSD Power Plant," Energy Transition BD, Dec. 09, 2022. https://www.energytransitionbd.org/post/aowrahati-100-mw-aggreko-hsd-power-plant (accessed Aug. 05, 2023).

[16] "Power plant and Calculations". https://www.powerplantandcalculaions.com/2020/05/steam-condenservacuum-and-calculations.html (Accessed: March 29, 2023).

Appendix A

Detailed Explanation

Code:

The Arduino Code is shown below

```
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 16, 2);
float input_voltage = 0.0;
float temp=0.0;

float input_voltage2 = 0.0;
float temp2=0.0;
  int analog_value;
    int analog_value2;
      int analog_value3;

float input_voltage3 = 0.0;
float temp3=0.0;

float r1=100000.0;//Bat +
float r2=10000.0;//gnd and junction for out


void setup()
{
   Serial.begin(115200);     //  opens serial port, sets data rate to 9600 bps
   lcd.begin();       //// set up the LCD's number of columns and rows:

}
void loop()
{

//Conversion formula

   analog_value = analogRead(A0);
    temp = (analog_value * 5.0) / 1024.0;
   input_voltage = temp / (r2/(r1+r2));

   if (input_voltage < 0.1)
   {
     input_voltage=0.0;
   }

    analog_value2 = analogRead(A1);
    temp2 = (analog_value2 * 5.0) / 1024.0;
    input_voltage2 = temp2 / (r2/(r1+r2));

   if (input_voltage2 < 0.1)
   {
     input_voltage2=0.0;
   }

    analog_value3 = analogRead(A2);
    temp3 = (analog_value3 * 5.0) / 1024.0;
    input_voltage3 = temp3 / (r2/(r1+r2));
```

```
  if (input_voltage3 < 0.1)
  {
    input_voltage3=0.0;
  }

   Serial.print("v2 ");
   Serial.println(input_voltage2);
   lcd.setCursor(0, 0);
   lcd.print("V1:");
   lcd.print(input_voltage);
   lcd.print(",V2:");
   lcd.print(input_voltage2);
   lcd.setCursor(0, 1);
   lcd.print("V3:");
   lcd.print(input_voltage3);


   delay(300);
}
```

Appendix B

Datasheet of the Chips used in the circuit.

1. Arduino Pro mini:

The Arduino Pro Mini is a compact and versatile microcontroller board based on the Atmel ATmega328P microcontroller. It is part of the Arduino family of open-source electronics platforms and is designed to offer a smaller, more lightweight, and cost-effective option for projects that require minimal space and power consumption.

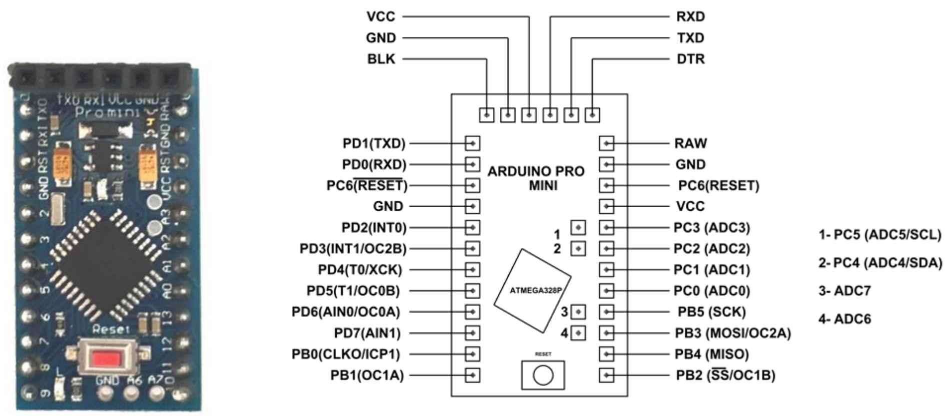


Fig 1: Arduino pro mini and Pinout.

The image above shows the physical image and pin diagram of the Arduino pro mini. The Arduino Pro Mini typically comes in two versions: one with 5V logic and another with 3.3V logic. The pin configuration is identical for both versions, but the 3.3V version operates at a lower voltage and frequency.

Please refer to the Table below for description of the table.

Pin	Function	Description
GND	Ground	Connected to the ground (0V) of the system.
VCC	Supply Voltage	Connected to a stable 5V power source.
RAW	Raw Input	Unregulated voltage input (within specified range) for voltage regulation.
RX	Receive (Serial)	TTL serial receive pin for data reception from external devices.
TX	Transmit (Serial)	TTL serial transmit pin for data transmission to external devices.
D2-D13	Digital I/O	Digital input/output pins used for communication and control.
A0-A7	Analog Input	Analog input pins for reading voltage levels from sensors/devices.
RESET	Reset	Pulling LOW momentarily resets the microcontroller.
AGND	Analog Ground	Ground reference for the analog-to-digital converter.
AREF	Analog Reference	Sets the reference voltage for the analog-to-digital converter.

2. 16X2 Display:

The 16x2 LCD module is a popular and widely used display device in electronics projects. It is a liquid crystal display (LCD) module with a resolution of 16 characters per line and 2 lines, hence the name "16x2." This type of display is commonly available and comes with a standard HD44780 controller, which makes it easy to interface with various microcontrollers and development boards.

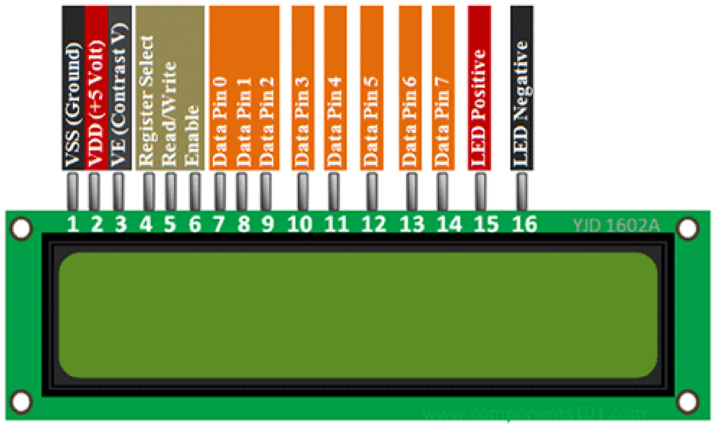


Fig 2: Pin Diagram of 16X2 LCD Display.

The Fig 2 above shows the pin diagram of standard 16x2 LCD display module. Please refer to the table below for the details of the pins.

Pin	Name	Function
1	VSS	Ground (0V) - Connect to the ground of the system.
2	VDD	Power Supply - Connect to +5V (or +3.3V) power source.
3	VEE	Contrast Voltage - Connect to a potentiometer to control the contrast of the display characters.
4	RS	Register Select - Selects the type of data (Instruction or Character Data) being sent to the LCD.
5	R/W	Read/Write - Controls the direction of data transfer between the microcontroller and the LCD.
6	EN	Enable - Latch data when transitioning from HIGH to LOW to process the data.
7-14	D0-D7	Data Bus - These pins (D0 to D7) carry the data sent to or received from the LCD.
15	A	Anode (+) of the LED Backlight (if available). Connect to +5V (or +3.3V) to enable the backlight.
16	K	Cathode (-) of the LED Backlight (if available). Connect to GND to enable the backlight.

3. I2C Serial Interface Adapter Module:

The I2C Serial Interface Adapter Module, commonly known as an I2C module or I2C LCD backpack, is a small add-on board that simplifies the interfacing of various devices with I2C (Inter-Integrated Circuit) communication protocol. It acts as a bridge between devices that use I2C and microcontrollers or development boards, providing an easy and efficient way to communicate with I2C-enabled peripherals.

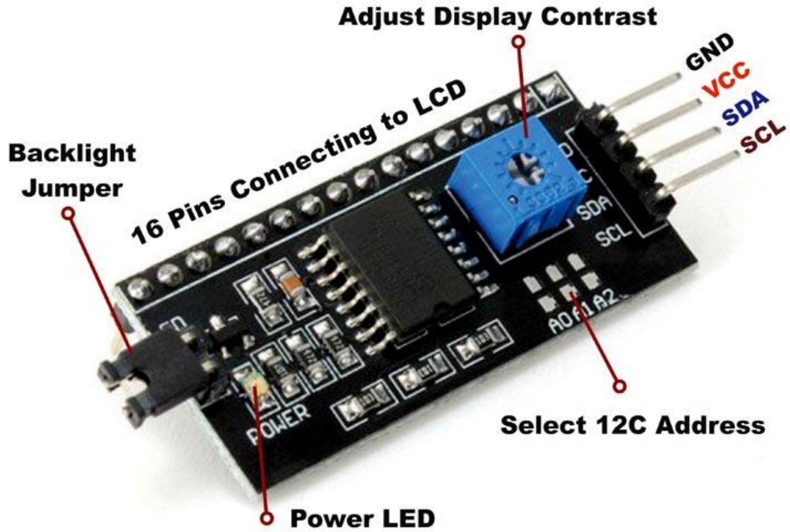


Fig 3: I2C Serial Interface Adapter Module Pinout.

The Fig 3 above shows the pinout diagram of I2C Serial Interface Adapter Module. For details of the pins please refer to the table below.

Pin	Name	Function
1	VCC	Supply Voltage (typically +5V)
2	GND	Ground
3	SDA	I2C Serial Data Line (connect to microcontroller's SDA pin)
4	SCL	I2C Serial Clock Line (connect to microcontroller's SCL pin)
5	A0	Address Bit 0 (used for I2C address configuration)
6	A1	Address Bit 1 (used for I2C address configuration)
7	A2	Address Bit 2 (used for I2C address configuration)
8	P0	Parallel I/O Pin 0 (usually not used in I2C communication)
9	P1	Parallel I/O Pin 1 (usually not used in I2C communication)
10	P2	Parallel I/O Pin 2 (usually not used in I2C communication)
11	P3	Parallel I/O Pin 3 (usually not used in I2C communication)
12	P4	Parallel I/O Pin 4 (usually not used in I2C communication)
13	P5	Parallel I/O Pin 5 (usually not used in I2C communication)
14	P6	Parallel I/O Pin 6 (usually not used in I2C communication)
15	P7	Parallel I/O Pin 7 (usually not used in I2C communication)

Plagiarism Report

M. Sc

ORIGINALITY REPORT

20%
SIMILARITY INDEX

PRIMARY SOURCES

1	dspace.aiub.edu Internet	672 words — 7%
2	community.element14.com Internet	133 words — 1%
3	fr.slideshare.net Internet	130 words — 1%
4	www.slideshare.net Internet	78 words — 1%
5	orca.cf.ac.uk Internet	75 words — 1%
6	Arman Sani, Eddy Warman, Ahmad Taufik, Suherman. "Experimental studies of the characteristics of the commercial thermoelectric sensor for heat energy harvesting", 2019 3rd International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM), 2019 Crossref	49 words — < 1%
7	es.scribd.com Internet	47 words — < 1%
8	documents.mx Internet	46 words — < 1%

9 Trevor Wayne Exley, Daniel Johnson, Amir Jafari. "Utilizing the peltier effect for actuation of thermo-active soft robots", Smart Materials and Structures, 2023 — 43 words — < 1%
Crossref

10 eprints.uthm.edu.my — 33 words — < 1%
Internet

11 S. Ashadevi, N. Meerakumari, M. Princeiga, S. Nanthakumar, L. Reshten Joe. "Advanced Industry Temperature Controlling and Energy Management System", 2022 3rd International Conference on Electronics and Sustainable Communication Systems (ICESC), 2022 — 32 words — < 1%
Crossref

12 Ramadass, Yogesh K., and Anantha P. Chandrakasan. "A Battery-Less Thermoelectric Energy Harvesting Interface Circuit With 35 mV Startup Voltage", IEEE Journal of Solid-State Circuits, 2011. — 31 words — < 1%
Crossref

13 ijpsat.ijsht-journals.org — 31 words — < 1%
Internet

14 vdocuments.site — 31 words — < 1%
Internet

15 store.arduino.cc — 30 words — < 1%
Internet

16 worldwidescience.org — 27 words — < 1%
Internet

17 hdl.handle.net — 24 words — < 1%
Internet

18	www.ijraset.com Internet	24 words — < 1%
19	Yanka Ivanova, Svetoslav Ivanov. "Dv/Dt Control Through the Gate of a Field-Effect Transistor in Forward-Mode Converters", 2021 12th National Conference with International Participation (ELECTRONICA), 2021 Crossref	23 words — < 1%
20	www.techtarget.com Internet	23 words — < 1%
21	www.indiamart.com Internet	22 words — < 1%
22	quieora.ink Internet	21 words — < 1%
23	microdigisoft.com Internet	20 words — < 1%
24	www.ijeast.com Internet	20 words — < 1%
25	dspace.iiuc.ac.bd:8080 Internet	19 words — < 1%
26	Abimbola, Adeniyi Ibukun. "Urban District Heating Network Delivery: A Socio-Technical Analysis of Large-Scale District Heating Network Implementation in Urban Environments", University of Salford (United Kingdom), 2023 ProQuest	17 words — < 1%
27	vital.seals.ac.za:8080 Internet	17 words — < 1%
28	www.sciencegate.app	

Internet

17 words — < 1%

29 repositorioacademico.upc.edu.pe
Internet
14 words — < 1%

30 umpir.ump.edu.my
Internet
14 words — < 1%

31 utpedia.utp.edu.my
Internet
14 words — < 1%

32 components101.com
Internet
13 words — < 1%

33 network.bepress.com
Internet
13 words — < 1%

34 repository.dl.itc.u-tokyo.ac.jp
Internet
13 words — < 1%

35 "The Role of Energy Management in Achieving Climate Neutrality in Municipalities in Europe", Riga Technical University, 2023
Crossref Posted Content
12 words — < 1%

36 2r-he.blogspot.com
Internet
12 words — < 1%

37 Wyk, Riaan van. "Non-Destructive Impact-Testing as a Method for Roof Bolt Integrity Analysis", University of Johannesburg (South Africa), 2023
ProQuest
12 words — < 1%

38 hephaestus.nup.ac.cy
Internet
12 words — < 1%

39	www.earnmoney.pk Internet	12 words — < 1%
40	forum.arduino.cc Internet	11 words — < 1%
41	journal.unimma.ac.id Internet	11 words — < 1%
42	wiki.doing-projects.org Internet	11 words — < 1%
43	Neva Agarwala. "International conference on advances in electrical engineering title: Thermoelectric measurements of silicon nanowire arrays for the seebeck effect", 2013 2nd International Conference on Advances in Electrical Engineering (ICAEE), 2013 Crossref	10 words — < 1%
44	dspace.daffodilvarsity.edu.bd:8080 Internet	10 words — < 1%
45	huzzaz.com Internet	10 words — < 1%
46	www.econjournals.com Internet	9 words — < 1%
47	Nipu Datta, Md N. Ahmed, Roksana Liya, Nazia Zaman, A. K. Mahbubul Hye, Bishwajit B. Pathik. "Maximizing the solar power by combine cycle: An experimental study on miniature solar power station", 2014 International Conference on Power System Technology, 2014 Crossref	8 words — < 1%
48	Radek Guráš, Miroslav Mahdal, Marian Bojko. "Heat transfer analysis of a liquid cooling device	8 words — < 1%

using thermoelectric elements", Applied Thermal Engineering, 2023
Crossref

49	Van der Merwe, Elmarie. "The Status of Material Master Data Management Implementation: Implications on Supply Chain Processes in FLSmidth", University of Johannesburg (South Africa), 2021 ProQuest	8 words — < 1%
50	digitalcommons.osgoode.yorku.ca Internet	8 words — < 1%
51	journals.pu.edu.pk Internet	8 words — < 1%
52	pt.slideshare.net Internet	8 words — < 1%
53	waset.org Internet	8 words — < 1%
54	www.iieta.org Internet	8 words — < 1%
55	www.threerivers.gov.uk Internet	8 words — < 1%

EXCLUDE QUOTES	OFF	EXCLUDE SOURCES	OFF
EXCLUDE BIBLIOGRAPHY	OFF	EXCLUDE MATCHES	OFF