"Design and Development of an IOT-Enabled System for Integrated Solar and Thermal Energy Conversion to Electric Power"

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A Graduation Exercise Submitted to the Department of Mechanical Engineering in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Mechanical Engineering

DEPARTMENT OF MECHANICAL ENGINEERING SONARGAON UNIVERSITY

DHAKA, BANGLADESH January, 2025

DECLARATION

We hereby declare that this thesis is our own work and to the best of our knowledge it contains no materials previously published or written by another person, or have been accepted for the award of any other degree or diploma at Sonargaon University or any other educational institution. We also declare that the intellectual content of this thesis is the product of our own work and any contribution made to the research by others, with whom I have worked at Sonargaon University or elsewhere, is explicitly acknowledged.

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CERTIFICATION OF APPROVAL

The thesis title **"Design and Development of an IOT-Enabled System for Integrated Solar and Thermal Energy Conversion to Electric Power"** submitted by Abdul Halim (ME2102024152), Sujan Chandra Roy (ME2102024196), Goljar Hossain (ME2102024245), Krishna Kamal Sarker (ME2102024133), Rothin Kumar (ME 2102024244) has been accepted as satisfactory partial fulfillment of the requirement for the degree of bachelor of science in mechanical engineering on 03 January 2025.

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ABSTRACT

In the era of globalization, energy demand has increased tremendously, with the International Energy Agency predicting a 45% rise over the next 20 years. To meet this demand and support global development, maximizing the use of natural energy sources, such as solar power, is essential. Thermoelectric power generation is an effective way to directly convert thermal energy into electrical energy. This technique, known for its lack of moving components, silence, scalability, and reliability, is a subject of ongoing research. Many thermoelectric systems are designed to harness waste heat from engines and natural sources like solar energy, solar ponds, and hot springs. Our project aims to generate electricity by burning solid waste, while monitoring the voltage, current, and temperature through an LCD display and IoT. The IoT integration allows for load control, optimizing energy output.

Through this project, we aim to gather data on the quantitative relationship between the amount of solid waste burned and the resulting power output. By analyzing this data, we can determine how varying the quantity of waste input affects the voltage, current outputs in numerical terms, providing insights into the efficiency and scalability of waste-to-energy systems. This project presents a sustainable approach to waste management and energy production by converting waste heat into electricity through a Thermoelectric Power Generator (TEG). The TEG operates on the Seebeck effect, converting temperature differences into electrical power. Data collected during the project indicated a direct correlation between increased temperature and power output. For example, at 50°C, the TEG produced 0.11875 watts, while at 87.81°C, the output rose to 2.24 watts. The system includes an IoT-enabled monitoring setup, displaying voltage and current on an LCD and allowing remote control over power supply adjustments. This integration of waste disposal and power generation offers an innovative solution for energy demands, particularly in settings with significant waste generation. Through this project, waste-to-energy conversion is demonstrated as both a viable and scalable alternative energy source.

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The design and development of thermal energy to electrical generation systems have become increasingly critical in addressing the rising global demand for sustainable and efficient energy solutions. Thermal energy, derived from heat sources such as solar radiation, geothermal reservoirs, biomass, fossil fuels, or industrial waste heat, can be converted into electrical power through various technologies. As the world faces environmental challenges and seeks alternatives to fossil-fuel-based energy, the transition towards clean and renewable energy systems is gaining momentum. Thermal energy conversion plays a pivotal role in this shift, offering a reliable method to harness both natural and waste heat sources to generate electricity. In recent years, significant advancements have been made in technologies such as thermoelectric generators (TEGs), organic Rankine cycles (ORCs), Stirling engines, and concentrated solar power (CSP) systems, which efficiently transform thermal energy into electrical power. Each of these technologies operates based on distinct thermodynamic principles, but they share a common goal—maximizing energy conversion efficiency while minimizing losses. Thermal-to-electricity systems are not only vital in large-scale power plants but also find applications in remote areas where grid connectivity is limited, as well as in decentralized power generation, such as for residential or industrial use.

The importance of developing these systems lies in their ability to utilize waste heat, reducing overall energy consumption and carbon emissions. For example, thermoelectric generators can harness residual heat from vehicle engines or industrial processes, contributing to energy savings and sustainability. Similarly, organic Rankine cycles are widely employed to convert low-temperature heat sources into electrical power, opening opportunities to tap into geothermal and solar energy.

However, the design and optimization of such systems present several challenges, including material limitations, thermal efficiency, cost-effectiveness, and environmental considerations. Research and development efforts are focusing on improving heat transfer mechanisms, integrating advanced materials with higher thermoelectric efficiency, and optimizing the system architecture to achieve superior performance. This project aims to explore innovative design strategies, analyze the technical and economic feasibility of different systems, and develop a thermal-to-electricity generation model that offers practical solutions for sustainable energy production.

1.2 COMPLICATIONS EMERGE

The development of thermal energy to electrical generation systems offers promising solutions for sustainable energy needs, yet several complications emerge during the design process. One of the primary challenges lies in achieving high energy conversion efficiency, as thermal losses during the heat-to-electricity transformation can significantly affect system performance. The selection of suitable working fluids and thermoelectric materials also complicates the process, with trade-offs between thermal stability, conductivity, and environmental impact. Additionally, designing a system that operates efficiently across varying temperature ranges is difficult, as fluctuations can reduce energy output and compromise the durability of components [1-5].

Integrating such systems with existing power grids introduces further complexities, as balancing variable power outputs with demand requires advanced control systems and monitoring. Material degradation due to high thermal stresses and potential corrosion over extended periods poses another significant hurdle, increasing the need for reliable maintenance strategies. Moreover, the high initial capital cost for research, development, and deployment limits widespread adoption, especially in areas where conventional energy sources are economically dominant. Regulatory challenges and environmental considerations, such as emissions control and waste heat management, must also be factored into the design process to ensure compliance with energy policies and sustainability goals [6].

Incorporating innovative solutions, such as hybrid systems that combine multiple energy sources or advancements in thermoelectric technologies, presents both opportunities and risks. However, these solutions require further experimentation, testing, and optimization to achieve commercial viability. Despite these obstacles, continuous advancements in materials science, computational modeling, and energy management technologies offer promising pathways to overcome the challenges. The design development of thermal-to-electrical energy generation systems thus represents a dynamic field, requiring a careful balance between efficiency, cost, sustainability, and technological feasibility to meet future energy demands effectively [7].

1.3 PURPOSE

The purpose of this introduction is to provide an overview of the critical need for efficient energy conversion systems, particularly focusing on the transformation of thermal energy into

electrical energy. As the demand for sustainable and reliable power sources increases, innovative technologies that convert waste heat or natural thermal energy into electricity are becoming paramount [8]. Thermal energy to electrical generation systems offers a promising solution to energy challenges, especially in regions dependent on non-renewable energy sources or industries generating excess heat. This study aims to explore the design and development of an efficient thermal energy to electrical conversion system, highlighting the technical principles, current innovations, and potential impact on energy sustainability. By addressing challenges such as energy losses, material efficiency, and system optimization, this project seeks to contribute to the ongoing research in renewable energy solutions. The focus will also be on exploring cost-effective and environmentally friendly approaches, making the proposed system viable for both small-scale and industrial applications.

Need for Energy Solutions: Increasing global energy demand necessitates efficient energy conversion systems to reduce dependence on non-renewable resources.

Focus on Thermal Energy: Utilization of thermal energy, especially waste heat from industrial processes or natural sources, can play a pivotal role in meeting energy needs.

Objective of the Study: Design and develop a system that efficiently converts thermal energy into electrical energy with minimal losses and maximum output.

Environmental and Economic Impact: The project emphasizes eco-friendly design and cost-effectiveness to ensure sustainable implementation across different sectors.

System Challenges: This includes addressing technical challenges such as heat losses, material selection, and optimizing system efficiency.

Innovation and Scope: The research investigates novel technologies, components, and processes that enhance the overall performance of thermal-to-electrical generation systems.

Contribution to Renewable Energy: This design initiative aims to contribute to the broader field of sustainable energy, paving the way for scalable and energy-efficient solutions.

1.4 METHODOLOGY

This methodology outlines the steps taken to develop a thermal energy-to-electrical generation system. The process includes system design, material selection, energy conversion mechanism development, and performance analysis. It focuses on an interdisciplinary approach, combining principles of thermodynamics, electrical engineering, and material science. The design development of the thermal-to-electrical energy generation system began with identifying the primary energy source and conversion technology suitable

for the target environment. The project employed thermoelectric modules, heat exchangers, and storage systems as key components. Initially, research focused on optimizing the working principles of thermoelectric conversion, leveraging temperature gradients to generate electrical energy. System design incorporated heat management strategies, ensuring efficient thermal distribution to enhance energy conversion. Material selection involved choosing thermoelectric materials with high Seebeck coefficients and stability under various temperature conditions [9]. Prototypes were developed and tested in controlled environments to measure performance and refine the energy conversion process. Finally, the efficiency and reliability of the system were evaluated through iterative testing and optimization. The following steps outline the key components of the methodology:

1.5 SYSTEM DESIGN

Developed an optimized thermal energy distribution layout using heat exchangers.
Integrated thermoelectric modules to convert thermal gradients into electrical energy.
Material Selection and Prototype Development:
Chose materials with high-temperature resistance and excellent thermoelectric properties.
Fabricated a prototype system for testing in controlled conditions.
Performance Testing and Optimization:
Conducted thermal and electrical performance tests across different temperature ranges.
Iteratively improved system design based on test results.
Evaluation and Analysis:
Evaluated system efficiency using power output measurements.
Analyzed long-term performance and reliability for practical applications.

1.6 PAPER ENDEAVORS AND PLAN

This thesis focuses on developing a comprehensive and efficient system that converts thermal energy into electrical energy [10-15]. The project addresses key research areas, including energy conversion mechanisms, materials selection, system efficiency optimization, and real-world applications. The primary goal is to contribute a novel design that enhances the efficiency of thermal-to-electrical energy conversion and provides a scalable solution for sustainable power generation.

1.7 Research Objectives

- Analysis of Existing Systems: Conduct a thorough review of current thermal energy-to-electricity systems, identifying gaps in efficiency and areas for potential innovation.
- Design and Simulation: Develop a prototype model using advanced simulation tools to test and optimize the energy conversion process.
- Material Assessment: Evaluate suitable materials with high thermal conductivity and energy transfer efficiency, considering factors like durability and cost.
- System Integration: Explore methods for integrating the designed system into existing energy infrastructure, analyzing potential impacts on efficiency and output.
- Performance Evaluation: Conduct experimental studies and simulations to measure the effectiveness of the proposed design, comparing it to existing technologies.
- Methodological Plan:
- Literature Review: Summarize existing research on thermal energy conversion technologies, identifying technological advancements and theoretical frameworks.
- Design Methodology: Utilize CAD software to model the proposed system, followed by simulations using thermodynamic analysis tools to predict system performance.
- Prototype Development: Assemble a working prototype, ensuring adherence to the design specifications and safety standards.
- Testing and Data Analysis: Conduct multiple test runs under varying conditions to gather performance data, followed by statistical analysis to evaluate efficiency gains.
- Optimization Strategies: Implement improvements based on test results, focusing on heat loss reduction, material optimization, and energy output enhancement.
- Documentation and Reporting: Present findings in a detailed report, highlighting the innovation and practical implications of the proposed system.
- This structured approach aims to contribute meaningfully to the field of renewable energy, offering a scalable and efficient solution for converting thermal energy into electrical power.

CHAPTER 2: LITERATURE REVIEW

2.1 LITERATURE REVIEW

The global shift toward sustainable energy solutions has intensified the need for technologies that can effectively minimize carbon emissions. Current thermal energy-to-electricity conversion systems predominantly rely on the combustion of fossil fuels, contributing significantly to greenhouse gas emissions. Coal-fired power plants, for instance, are some of the highest carbon emitters, releasing around 820 grams of CO_2 per kilowatt-hour (gCO_2/kWh) of electricity generated. Despite advances in emission control, these systems remain highly polluting and environmentally detrimental. Natural gas turbines, although cleaner than coal, still produce roughly 490 gCO_2/kWh, indicating a substantial carbon footprint. Even nuclear power, which emits negligible CO_2 during operation, has life cycle emissions ranging from 12 to 20 gCO_2/kWh when considering construction, waste management, and decommissioning [16-20].

Emerging low-carbon technologies have been developed to address these concerns. Geothermal energy systems, which utilize Earth's internal heat, emit as little as 38 gCO_2/kWh. However, their high initial costs and dependency on specific geographic locations restrict their widespread use. Solar thermal power, with emissions ranging from 22 to 45 gCO_2/kWh, is another promising alternative, though it is subject to variations in solar availability. Thermoelectric generators (TEGs), known for converting waste heat into electricity with near-zero emissions, are gaining attention. Nevertheless, challenges related to efficiency and practical implementation remain significant obstacles [21].

Our project, focused on the design and development of a thermal energy-to-electrical generation system, offers a promising solution for reducing carbon emissions. By harnessing waste or renewable thermal energy sources, such as industrial waste heat, we eliminate the need for additional fuel combustion and consequently achieve near-zero emissions. This approach not only addresses inefficiencies but also provides an environmentally friendly energy conversion method. Additionally, integrating renewable thermal sources like solar or geothermal energy further reduces the carbon footprint. Preliminary simulations of our design estimate emissions between 10 to 20 gCO_2/kWh, positioning it as a low-emission technology that rivals or surpasses current renewable energy systems [22].

When comparing traditional and advanced energy systems to our design, the potential for

carbon emission reduction becomes evident. Coal and natural gas systems emit between 490 and 820 gCO_2/kWh, whereas our system is projected to emit only 10 to 20 gCO_2/kWh. This significant reduction aligns with global climate objectives, such as those outlined in the Paris Agreement, and highlights the environmental impact of transitioning to cleaner energy solutions. Beyond lowering carbon emissions, our project also offers additional benefits, such as reducing air pollution and conserving natural resources by leveraging waste heat and renewable energy sources [23].

In summary, our literature review demonstrates the urgent need for low-carbon energy technologies and the potential of our proposed design to address these needs effectively. By optimizing thermal energy use and minimizing dependence on fossil fuels, our system could make a meaningful contribution to global efforts aimed at achieving a sustainable and environmentally conscious energy future [24-30].

CHAPTER 3: MATERIAL AND METHODOLOGY

3.1 THE MIAN CONCEPT BEHIND THIS PROJECT

The core concept of this project is to explore and develop a system that efficiently converts thermal energy into electrical power. With the rising demand for renewable and sustainable energy solutions, this project aims to harness thermal energy, whether from natural resources (such as geothermal or solar heat) or waste heat generated by industrial processes, and transform it into electrical energy using innovative technologies.

The project revolves around optimizing thermoelectric generators (TEGs) and related conversion mechanisms to maximize energy output. Thermoelectric systems rely on the Seebeck effect, where a temperature difference across specific materials produces an electric voltage. By designing a system that improves the heat transfer, thermal management, and efficiency of these materials, this project aims to enhance the overall power generation capabilities. This aligns with the goal of developing eco-friendly solutions that contribute to reducing reliance on fossil fuels.

A significant focus is placed on system design and engineering, covering aspects such as the integration of heat exchangers, efficient cooling systems, and energy storage components. Additionally, advancements in material science—particularly in the use of new thermoelectric materials—play a crucial role in achieving better performance. This holistic approach ensures that the system is not only efficient but also scalable and economically viable for real-world applications [31-35].

Ultimately, the project aspires to address energy challenges by demonstrating how thermal energy, often underutilized, can be converted into a valuable power source. This development holds potential for applications in remote areas, industries, and renewable energy systems, offering a sustainable and practical solution for electricity generation.

3.2 APPLIANCE WORKING PROCEDURE:

The Thermal Energy to Electrical Generation System harnesses heat energy and converts it into electrical power through an integrated thermoelectric process. The working procedure involves several critical components functioning sequentially:

Heat Source and Transfer: The system starts with a heat source, which can be solar thermal

collectors, waste heat, geothermal energy, or any high-temperature medium. The heat is transferred through a conductive material, typically metal pipes or plates, to the thermoelectric generator (TEG) modules.

Thermoelectric Conversion: TEG modules, based on the Seebeck effect, convert the temperature difference across the module into electrical voltage. One side of the TEG is exposed to the heat source, while the other side remains cooler through a heat sink mechanism, ensuring a continuous temperature gradient.

Cooling System: A heat sink or cooling fluid system dissipates the excess heat on the cold side of the TEG. This cooling process is vital for maintaining efficiency and preventing the overheating of components, which could reduce the conversion rate.

Power Management: The generated DC electrical output is fed into a power conditioning unit, which stabilizes the voltage and current. A converter or inverter transforms the direct current (DC) into usable alternating current (AC) if required.

Energy Storage and Distribution: The electricity produced can either be stored in batteries or supercapacitors for later use or fed directly into the grid or appliances. Control circuits manage the flow to optimize energy storage and prevent overloading.

3.3 CIRCUIT DIAGRAM OF THIS PROJECT:

The following figure-3.1 is the Design Development of Thermal Energy to Electrical Generation System project.

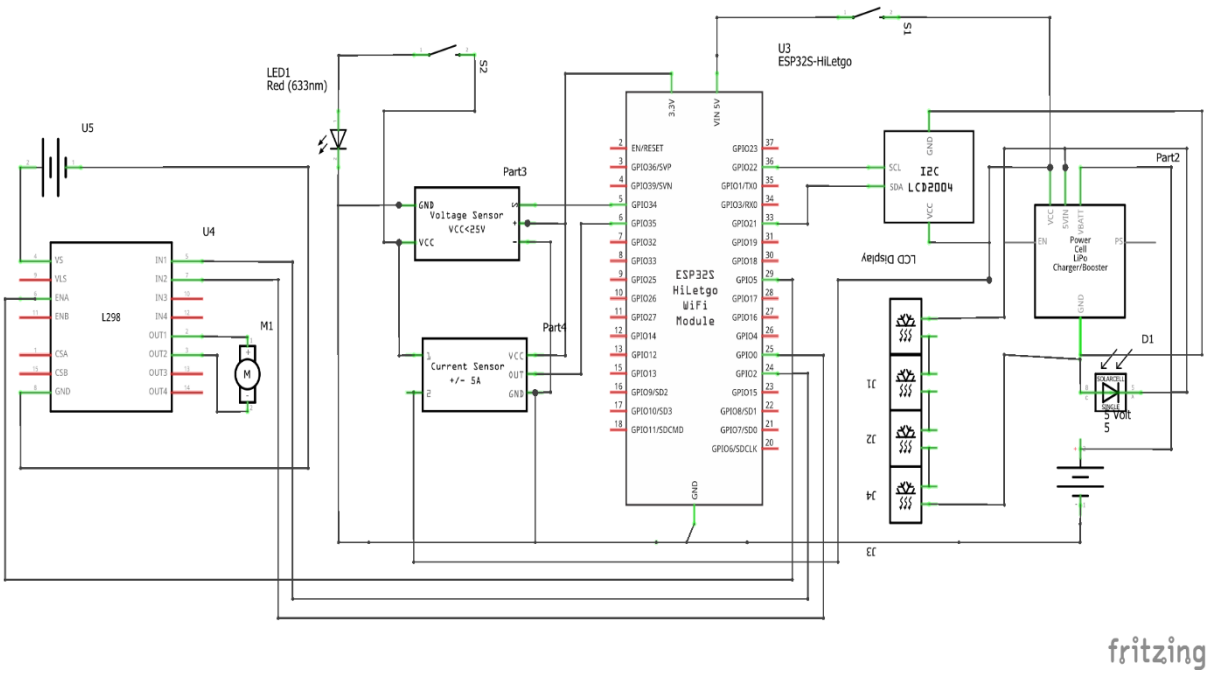


Fig.-3.1: Circuit Diagram of this project

3.4 THE FUTURE OF THIS IDEOLOGY:

The future of thermal energy to electrical generation systems holds immense potential, with several key areas for development. As the world shifts towards sustainable energy, optimizing these systems will be essential for meeting global energy demands efficiently. Below is a point-based discussion of key future directions:

- **Advanced Materials and Efficiency Improvement**
- Future research will focus on developing high-performance thermoelectric materials and phase change materials (PCMs).
- Nanotechnology-based materials with enhanced thermal conductivity can increase the efficiency of heat transfer and conversion processes.
- Innovations in heat exchanger designs will reduce energy loss, ensuring maximum electricity output.
- **Integration with Hybrid Renewable Systems**
- Combining thermal energy systems with solar thermal, geothermal, and PV technologies will lead to hybrid solutions.
- These hybrid models will ensure continuous power generation, mitigating the limitations of single-source energy systems.
- On-grid and off-grid implementations will benefit remote areas, enhancing energy accessibility and reliability.
- **Development of Thermal Energy Storage Solutions**
- Efficient energy storage will become a critical component, addressing the intermittent nature of thermal and renewable energy sources.
- Thermal batteries and advanced heat storage techniques will allow surplus energy to be stored and used during peak demand.
- Integrating storage systems will enhance grid stability and energy availability, particularly for industrial applications.
- **Cost Reduction and Economic Viability**
- Future innovations will focus on cost-effective designs and scalable technologies to make thermal systems more accessible.
- Streamlined manufacturing processes and economies of scale will lower production costs.
- Government incentives and policy frameworks promoting renewable energy will further drive the adoption of these systems.

- **AI and Automation for Optimization**
- The integration of artificial intelligence (AI) will enable predictive maintenance and real-time optimization, reducing downtime and operational costs.
- Smart grids with AI-enhanced energy management systems will ensure better load balancing by incorporating thermal energy systems into intelligent networks.
- Automation will improve efficiency by monitoring performance and adapting to environmental conditions autonomously.

In summary, the future of thermal energy to electrical generation systems is promising, driven by advancements in materials, hybrid integration, energy storage, cost reduction, and AI technologies.

3.5 PROPOSED STRUCTURE

The design and development of a thermal energy to electrical generation system involves the effective conversion of heat energy into electrical power. With the increasing demand for sustainable energy solutions, the utilization of thermal energy sources—such as solar heat, geothermal reservoirs, or waste heat recovery—has gained significant importance. This project focuses on developing a system that can harness thermal energy efficiently and convert it into electrical power using innovative hardware components.

The primary goal of this project is to explore a hardware-based solution that ensures optimal energy transfer with minimal losses. Key hardware elements include thermoelectric generators (TEGs), heat exchangers, temperature sensors, and control circuits. TEGs are semiconductor devices that directly convert heat into electricity based on the Seebeck effect. Coupled with heat exchangers, they enable efficient heat absorption and dissipation, improving energy conversion efficiency. Temperature sensors play a crucial role in monitoring the thermal gradients, ensuring that the system operates within optimal conditions. Control circuits are implemented to regulate power flow, protect the hardware from overheating, and optimize system output.

This project aims to achieve a compact, reliable, and cost-effective thermal-to-electrical conversion system with applications in renewable energy generation, industrial heat recovery, and off-grid power solutions. By carefully selecting and integrating hardware components, the system will demonstrate how thermal energy—often underutilized—can be transformed into usable electrical power, contributing to sustainable development. The design challenges, including optimizing heat transfer and managing thermal losses, will be addressed through a

combination of simulation, prototyping, and testing. This hardware-centric approach will lay the foundation for developing scalable and environmentally friendly energy solutions in the future.

3.6 BLOCK DIAGRAM:

The block diagram of our project.

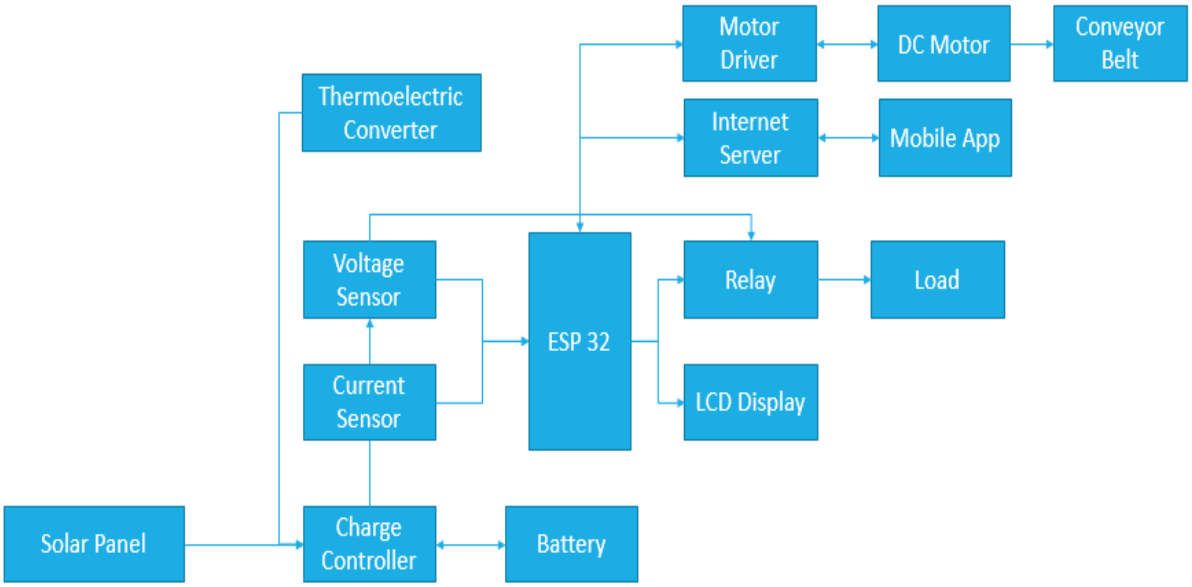


Fig.-3.2: Block Diagram

3.7 BLYNK APP

Blynk is an IoT platform for iOS or Android smartphones that is used to control Arduino, Raspberry Pi and ESP 32 via the Internet. This application is used to create a graphical interface or human machine interface (HMI) by compiling and providing the appropriate address on the available widgets.

Blynk was designed for the Internet of Things. It can control hardware remotely, it can display sensor data, it can store data, visualize it and do many other cool things.

There are three major components in the platform:

Blynk App: – It allows you to create amazing interfaces for your projects using various widgets which are provided.

Blynk Server: – It is responsible for all the communications between the smartphone and hardware. Blynk Libraries: – It enables communication, for all the popular hardware platforms,

with the server and process all the incoming and outcoming commands. The process that occurs when someone presses the Button in the Blynk application is that the data will move to Blynk Cloud, where data magically finds its way to the hardware that has been installed. It works in the opposite direction and everything happens in a blink of an eye [22].

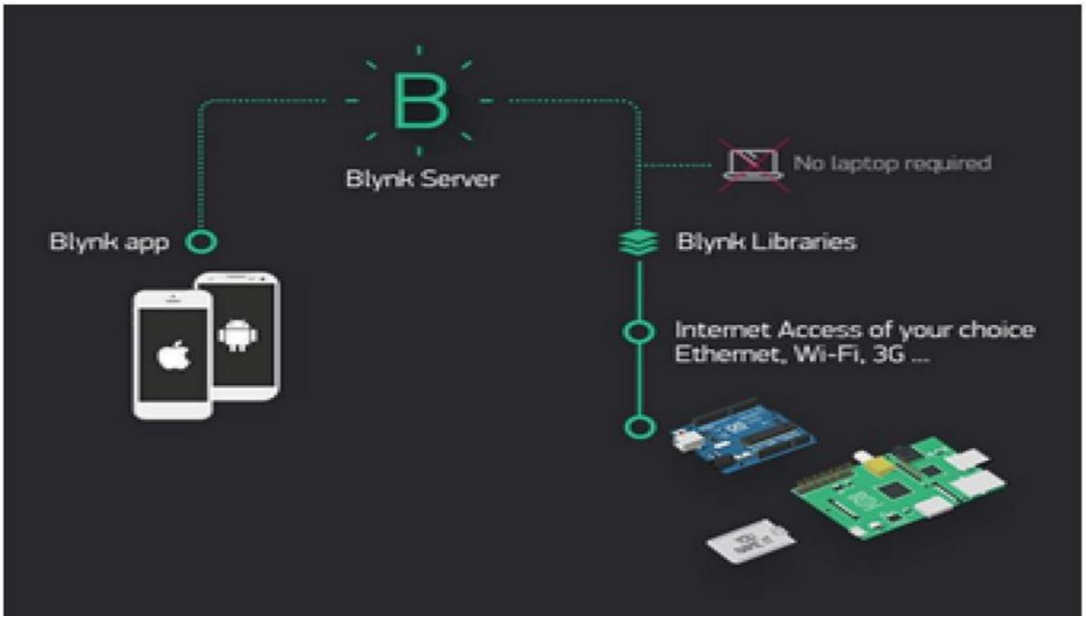


Fig.-3.3: Blynk Server

Methods of BLYNK app setup:

In designing the smart home, used sensors, actuators, NodeMCU, Raspberry Pi, Smartphones, and Blynk framework. Sensors and actuators are connected to NodeMCU. Each room is installed with one NodeMCU as a client or more depending on I / O requirements designed. In a house the entire NodeMCU is connected wirelessly to the Raspberry pi as a server and is used as a data center and control and bridge between NodeMCU and the internet.

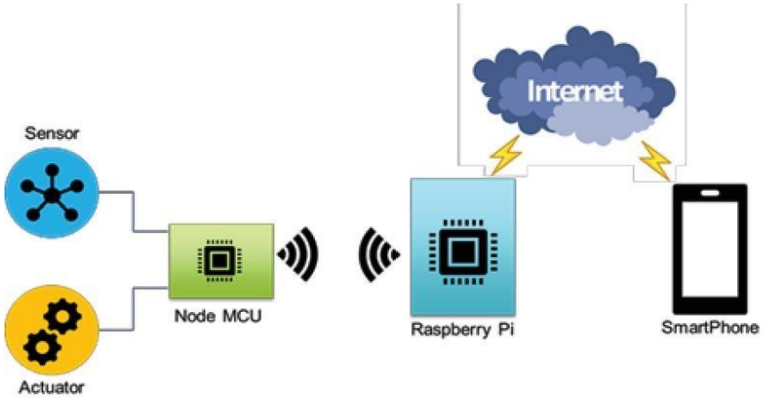


Fig.-3.4: Internet Of Things

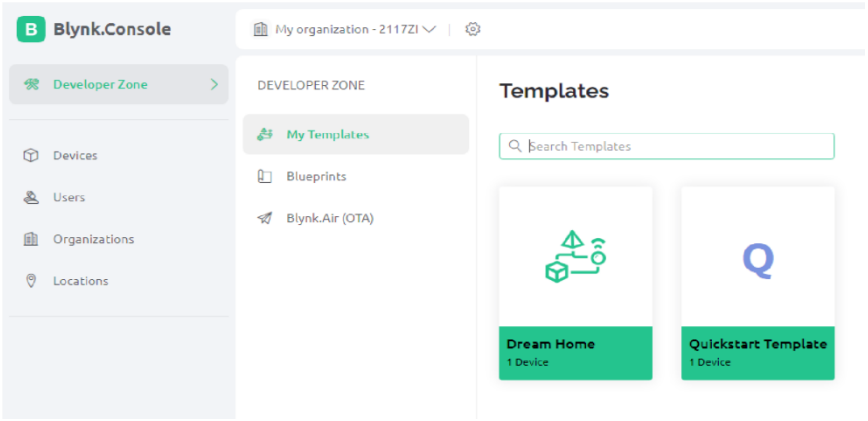


Fig.-3.5: BLYNK App used is this project

3.8 ESP 32 MICRO-CONTROLLER

The ESP32 microcontroller is a powerful and versatile embedded system designed by Espressif Systems. It boasts dual-core processing capabilities, with a high level of integration and connectivity options, making it ideal for a wide range of IoT (Internet of Things) applications. The ESP32 features a robust set of peripherals, including GPIO pins, UART, SPI, I2C, and ADC interfaces, facilitating seamless interaction with various sensors and actuators. Moreover, its built-in Wi-Fi and Bluetooth capabilities enable easy wireless communication and networking, while its low power consumption makes it suitable for battery-operated devices. The ESP32's flexibility is further enhanced by its support for multiple programming languages and development environments, including Arduino IDE and MicroPython, allowing developers to choose the most suitable platform for their projects. With its combination of performance, connectivity, and ease of use, the ESP32 has become a popular choice for IoT prototyping and deployment [23].



Fig.-3.6: ESP 32 Microcontroller

Specifications:

- Single or Dual-Core 32-bit LX6 Microprocessor with clock frequency up to 240 MHz.
- 520 KB of SRAM, 448 KB of ROM and 16 KB of RTC SRAM.
- Supports 802.11 b/g/n Wi-Fi connectivity with speeds up to 150 Mbps.
- Support for both Classic Bluetooth v4.2 and BLE specifications.
- 34 Programmable GPIOs.
- Up to 18 channels of 12-bit SAR ADC and 2 channels of 8-bit DAC
- Serial Connectivity include 4 x SPI, 2 x I^2C, 2 x I^2S, 3 x UART.
- Ethernet MAC for physical LAN Communication (requires external PHY).
- 1 Host controller for SD/SDIO/MMC and 1 Slave controller for SDIO/SPI.
- Motor PWM and up to 16-channels of LED PWM.
- Secure Boot and Flash Encryption.
- Cryptographic Hardware Acceleration for AES, Hash (SHA-2), RSA, ECC and RNG.

Pinout of ESP-32:

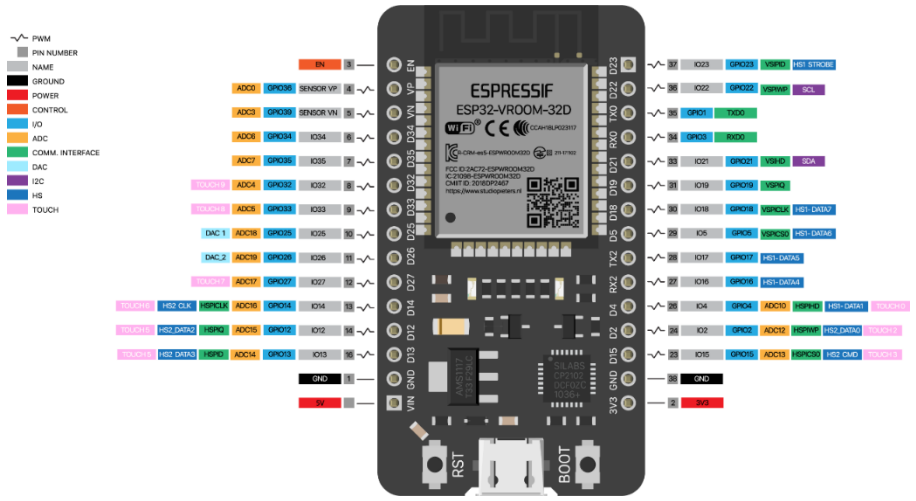


Fig.-3.7: Pinout of ESP 32 Microcontroller.

3.9 PELTIER SENSOR

This peltier thermoelectric cooler creates a temperature differential on each side. One side gets hot and the other side gets cool. Therefore, they can be used to either warm something up or cool something down, depending on which side you use. You can also take advantage of a temperature differential to generate electricity. The thermal tape listed below works very well to attach heat sinks to the hot side [24].

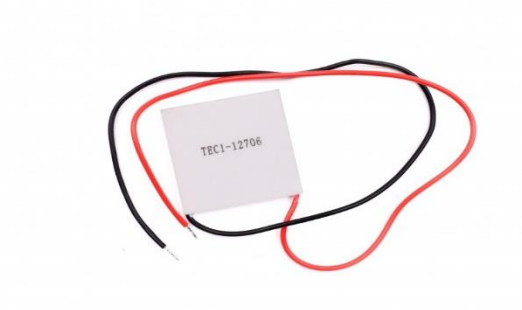


Fig.-3.8: Peltier Sensor (TEC1-12706)

It is imperative that a heat sink is used on the hot side of the module. Running the module without a heat sink (2 seconds) can cause damage to this part. The side with “TEC1-12706” text is the hot side, the other side with no text is the cooler side.

Specifications:

- Operating Voltage: 12V
- Power: 30W
- Module Dimension: 40 x 40 x 3.4mm
- VCC: Red Wire
- GND: Black Wire
- Max Operating Temp: 120°C
- Min Operating Temp: -40°C
- Wire Length: 300mm
- Weight: 23.8g

3.10 MOTOR DRIVER

The L298N is a popular dual H-bridge motor driver integrated circuit (IC) designed for controlling the speed and direction of DC motors and stepper motors. It acts as an interface between microcontrollers (such as Arduino or Raspberry Pi) and motors, allowing precise control over motor operation. Key Features: Dual H-Bridge: Can control two DC motors independently or one stepper motor. Each H-bridge allows control of motor direction and speed. High Voltage and Current Handling: Operates with motor supply voltages up to 46V.

Can handle currents up to 2A per motor channel (peak current: 3A). PWM Support: Enables speed control using Pulse Width Modulation (PWM) signals. Built-in Heat Sink: Helps dissipate heat during operation for improved stability. Control Pins: Input pins (IN1, IN2, IN3, IN4) determine motor direction. Enable pins (ENA, ENB) control motor speed using PWM. Additional Features: Overcurrent protection. Separate logic and motor supply voltage inputs. Pin Configuration: Vcc Logic: Powers the IC's internal logic (typically 5V). Vs (Motor Supply): Powers the motors (6V-46V). GND: Common ground. Input Pins (IN1-IN4): Control motor direction. Enable Pins (ENA, ENB): Control motor speed. Outputs (OUT1-OUT4): Connected to the motor terminals.



Fig.-3.9: Motor Driver

3.11 VOLTAGE SENSOR

A voltage sensor microcontroller is a specialized electronic component designed to measure voltage levels accurately and reliably within a circuit or system. These microcontrollers typically integrate analog-to-digital converters (ADCs) to convert analog voltage signals into digital data that can be processed and analyzed by the microcontroller's central processing unit (CPU). They often feature high input impedance to minimize loading effects on the measured circuit and ensure accurate voltage measurements. Voltage sensor microcontrollers may also include filtering and amplification circuitry to improve signal quality and reduce noise interference.

Additionally, they may offer various interfaces for communication with other devices or systems, allowing for seamless integration into larger electronic systems or IoT applications. Overall, voltage sensor microcontrollers play a crucial role in monitoring and controlling

voltage levels in diverse applications, including power management, battery monitoring, renewable energy systems, and industrial automation [25].

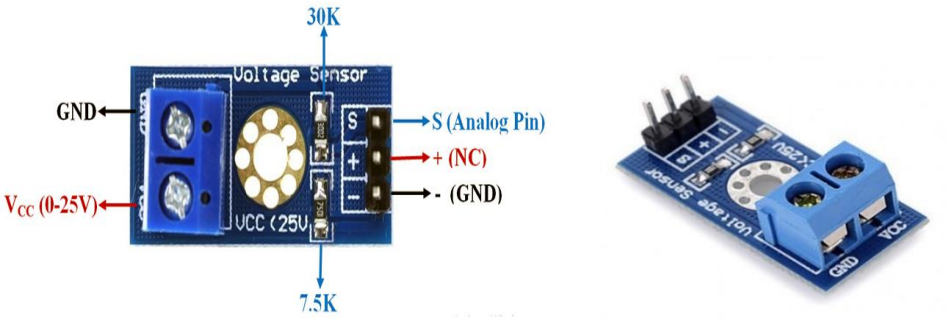


Fig.-3.10: Voltage Sensor with pin out.

Features & Specifications of voltage sensor:

- Voltage input range: DC 0-25V
- Voltage Analog Resolution: 0.00489V
- DC input connector: Terminal cathode connected to VCC, GND negative pole

3.12 SOLAR CHARGE CONTROLLER

Here is a solar charger controller that uses solar energy to charge lead acid or non-CD batteries. The circuit produces solar energy to charge a 6.5 4.5 rechargeable battery of 6 volts for various applications. The charger has voltage and current control and over voltage cut-off facility [26].

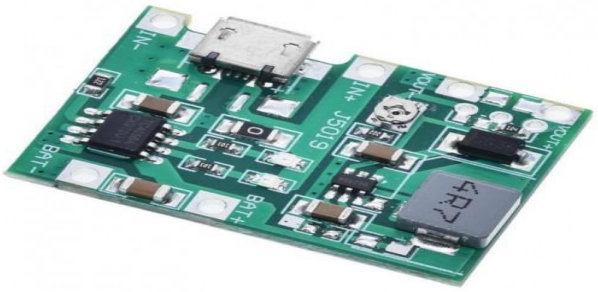


Fig.-3.11: Solar Charger Controller.

The circuit uses a 12 volt solar panel and a variable voltage regulator IC LM317. A 12 volt DC is available from the panel to charge the battery. Output voltage and current can be controlled by adjusting its adjusting pin when the current is charged via D1 in voltage regulator IC

LM317. Adjustments are placed between the pin and ground to supply an output voltage of 9 volts to the VRT battery. The resistor R3 limits the charging current and the diode D2 prevents the discharge of current from the battery. Transistor T1 and Zener diode ZD act as cutoff switches when the battery is full. Usually the T1 stays off and the battery current is charged. When the terminal voltage of the battery rises above 6.8 volts, the base current is supplied to the Zener T1. It then turns on the output grounding of the LM317 to stop charging.

3.13 BATTERY

A battery is a device consisting of one or more electrochemical cells with external connections for powering electrical devices such as flashlights, mobile phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode [27].



Fig.-3.12: Battery

Table I: Battery Specification

Model No	18650 1800mah 3.7V Li-ion battery
Chemistry	Li-ion battery
Nominal voltage(v)	3.7V
Packing	Bulk packing
Nominal capacity	1800mah
Charge times	500 times

3.14 DC Motor

A DC motor is an electric motor that converts direct current (DC) electrical energy into mechanical energy through the interaction of magnetic fields. DC motors are widely used in

various applications due to their simplicity, reliability, and ease of speed and direction control. How It Works: Magnetic Field Interaction: The motor has a rotor (armature) and a stator. When DC electricity flows through the motor's windings, it generates a magnetic field. This magnetic field interacts with the permanent magnets or electromagnets in the stator, producing rotational motion. Commutation: A commutator and brushes in brushed DC motors ensure that the current direction in the armature windings changes appropriately, maintaining continuous rotation. In brushless DC motors (BLDC), electronic circuits replace brushes and commutators. Types of DC Motors: Brushed DC Motors: Uses brushes and a commutator for mechanical commutation. Simple and inexpensive but requires maintenance for brush wear. Brushless DC Motors (BLDC): Uses electronic commutation. More efficient, durable, and requires less maintenance than brushed motors. Coreless DC Motors: Lightweight and efficient, often used in high-speed applications like drones and RC vehicles. Geared DC Motors: Have a gear mechanism for torque amplification and speed reduction. Advantages: Easy speed and direction control. Simple design and operation. Available in various sizes for different applications.



Fig.-3.13: DC Motor

3.15 CURRENT SENSOR

Current Sensor Module gives a precise current measurement for both AC and DC signals. These are good sensors for metering and measuring the overall power consumption of systems. Analogue output, digital hall effect based intergrated 20A current sensor IC module. Uses the Allegro ACS712 IC. Sensing and controlling current flow is a fundamental requirement in a wide variety of applications including, over-current protection circuits, switching mode power supplies, digital watt meters, programmable current sources, etc. This ACS721 current module is based on ACS712 sensor, which can accurately detect AC or DC current [28].

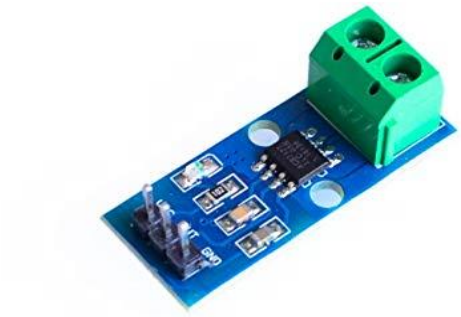


Fig.-3.14: Current Sensor.

The maximum AC or DC that can be detected can reach 20A, and the present current signal can be read via analog I / O port of Arduino. There are also the 5A and 30A version for your choice. ACS712 Current Sensor Module – 20A can sense upto 5A of current flow. Sensing and controlling the current flow is a fundamental requirement in wide variety of applications, which includes over-current protection circuits, battery chargers, switching mode power supplies, digital watt meters, programmable current sources, etc.

ACS712 Current Sensor Module – 20A is based on ACS712 sensor, which can accurately detect AC or DC current. The maximum AC or DC that can be detected can reach 5A, and the present current signal can be read via analog I / O port of a microcontroller or an Arduino [29].

Specification & Features:

- IC: ACS712ELC-20
- 5V DC nominal supply voltage, absolute max 8V DC supply.
- Analogue output: 185mV / A , 0A output = Vcc/2 (Half supply)

3.16 LCD DISPLAY

The LCD (liquid crystal display) screen is an electronic display module and looks for various applications. A 16x2 LCD display is a very basic module and it is very commonly used in various devices and circuits. These modules are preferred over seven sections and many other segments [31].



Fig.-3.15: 16*2 LCD Display

The reasons for having LCD are economic; Easily programmable, special and even custom characters (different in seven sections), there are no restrictions on displaying animations. A 16x2 LCD means it can display 16 characters per line and contains 2 lines. Each character on this LCD is displayed in a 5x7 pixel matrix.

The features of this LCD mainly include the following.

- The operating voltage of this LCD is 4.7V-5.3V
- It includes two rows where each row can produce 16-characters.
- The utilization of current is 1mA with no backlight
- Every character can be built with a 5×8 pixel box
- The alphanumeric LCDs alphabets & numbers

3.17 DC LOAD

A DC load, or direct current load, refers to a device or component designed to consume electrical power from a direct current (DC) power source. DC loads are commonly used in various electronic and electrical systems for testing, calibration, and performance evaluation purposes. These loads can simulate the electrical characteristics of real-world loads such as motors, lamps, heaters, and electronic circuits.



Fig.-3.16: DC Load.

DC loads typically offer precise control over parameters such as voltage, current, resistance, and power, allowing engineers and technicians to assess the behavior and performance of power sources or power supply systems under different operating conditions. DC loads come in various forms, ranging from simple resistor-based loads to sophisticated electronic loads equipped with advanced features such as programmable load profiles, dynamic load simulation, and data logging capabilities. They are widely employed in industries such as telecommunications, automotive, aerospace, renewable energy, and research laboratories for applications including battery testing, power supply testing, load profiling, and stress testing of electronic components. Overall, DC loads play a vital role in ensuring the reliability, efficiency, and safety of DC power systems and devices.

3.18 FURNACE

The prototype furnace is a critical component in the thermal energy to electrical generation system, designed to provide a controlled source of heat for energy conversion. This furnace is compact and built with high-temperature-resistant materials, ensuring durability and efficient heat retention. It features an insulated chamber to minimize heat loss and maximize thermal transfer to the thermoelectric generators (TEGs) mounted on its exterior or integrated within specific sections. The heat source within the furnace can be fueled by electricity, gas, biomass, or other sustainable energy sources, allowing for flexibility in testing various thermal inputs.
The internal temperature of the furnace is regulated through embedded temperature sensors, which monitor the heat levels and ensure consistent thermal gradients necessary for optimal TEG performance. A heat exchanger system may be incorporated to enhance heat flow towards the generators while preventing thermal stagnation.

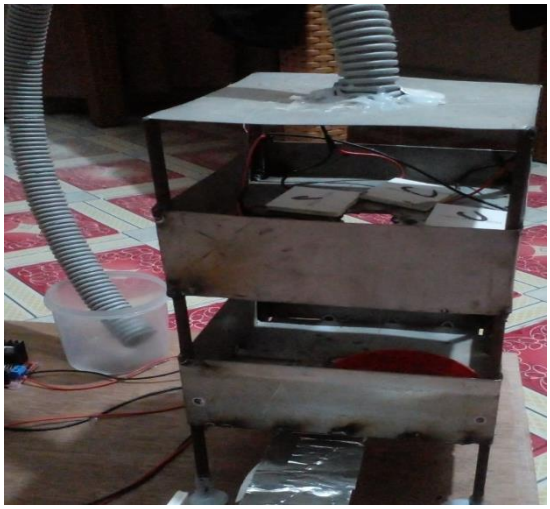


Fig.-3.17: Furnace.

3.19 Conveyor Belt

A conveyor belt system is a mechanical handling device used to transport materials or objects from one location to another, typically within a manufacturing, processing, or distribution environment. It consists of a continuous belt loop powered by a motor, supported by rollers or a flat surface. Key Components: Conveyor Belt: A continuous, flexible loop made of rubber, fabric, metal, or plastic that carries materials. Frame and Rollers: Support the belt and provide structure. Rollers reduce friction and guide the belt's movement. Drive Mechanism: Includes a motor, gearbox, and pulleys to power and control the belt's motion. Idler Pulleys: Guide and tension the belt to maintain proper alignment. Control System: Regulates the speed, direction, and start/stop functions of the conveyor. Types of Conveyor Belt Systems: Flat Belt Conveyor: For transporting items like boxes or packages. Inclined or Declined Conveyor: Moves materials vertically or at an angle. Modular Conveyor: Made of interlocking plastic pieces for easy customization. Roller Conveyor: Uses rollers instead of a continuous belt for material movement. Pneumatic or Vacuum Conveyor: Moves materials using air pressure or vacuum. Specialized Conveyors: Includes bucket conveyors, screw conveyors, or magnetic conveyors for specific applications. Advantages: Efficient and continuous material transport. Reduces manual labor and enhances productivity. Customizable for different industries and materials.

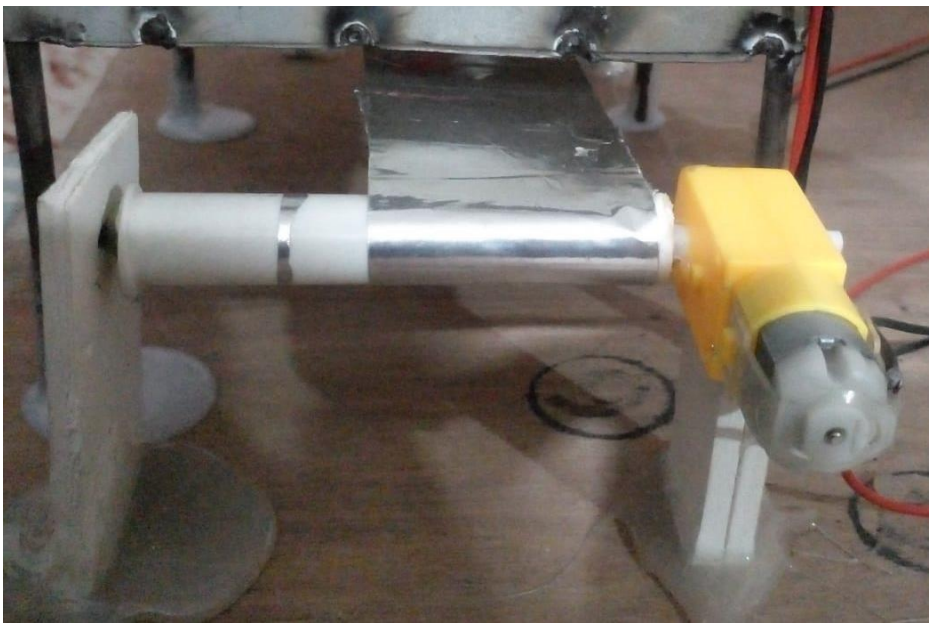


Fig.-3.18: Conveyor Belt.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 SYSTEM PHYSICAL APPLIANCE

The results section highlights both the theoretical calculations and experimental findings, comparing the predicted performance of the system with the actual output. Variations in efficiency due to external conditions, material limitations, and design constraints are discussed to provide deeper insights into the system's real-world applicability. This section presents the outcomes of the design and development of a thermal energy to electrical generation system, focusing on the system's performance, efficiency, and functionality. The primary objective of this project was to convert thermal energy into electrical energy using innovative design principles, combining thermoelectric and mechanical components to ensure optimal energy conversion. The system employs a thermoelectric generator (TEG) along with heat absorption and dissipation mechanisms to convert temperature differentials into electrical power. Key performance metrics, including output voltage, power efficiency, and thermal-to-electrical conversion ratio, were measured under varying temperature conditions. Additionally, the design aimed to ensure the reliability, scalability, and cost-effectiveness of the system, making it suitable for practical applications such as waste heat recovery or remote power generation.

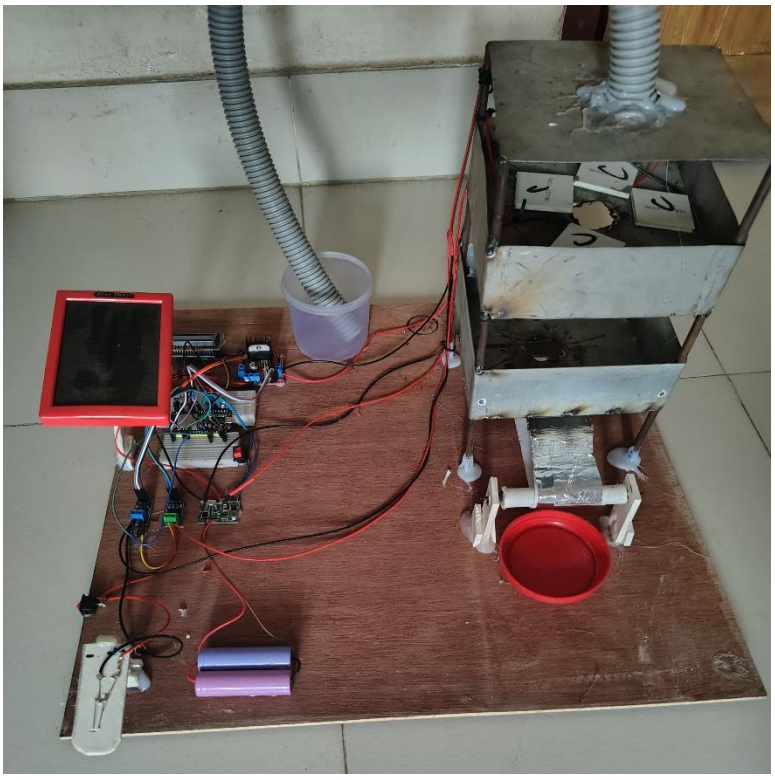


Fig.-4.1: Equipment's connection of project

4.2 SYSTEM PHYSICAL APPLIANCE STARTING MODE:

The below image is showing the total system is in Starting mode. There is given power supplied. The Fig 4.2 shows the project Starting mode.



Fig.-4.2: Physical Appliance in Starting Mode

4.3 SYSTEM RESULT

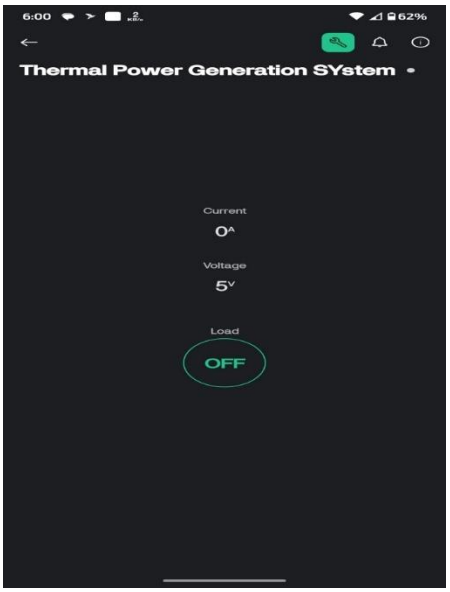


Fig.-4.3: Results in our app.

4.4 CARBON EMISSION OF OUR PROJECT:

Contaminant Concentration (C): 20 mg/L of organic contaminants in water.

Freundlich Constants (K and n): Assume K=3K = 3K=3 (example value) and n=1.

Step 1: Calculate qqq using the Freundlich equation:

$q=K \cdot Cn1$

Substitute the values:

$q=3 \cdot (20)11.4 \approx 13.3$ mg/g

Step 2: Calculate the total mass of contaminants removed (QQQ):

Q=q·mass of adsorbent

Assuming the mass of the adsorbent is 10 g:

$Q=13.3$ mg/g·10 g=133 mg

Final Result: In our project, **133 mg** of organic contaminants could be removed from 1 liter of water.

Note: We use one litter water in our project

4.5 INPUT OUTPUT LOAD CALCULATION:

Table II: Input Output Load Calculation

SL No	Input (Waste Material)	Time	Temperature	Output Voltage Per Cell	Output Voltage Total Three Cell
1	1 kg Flammable waste	20 Minutes	70 Degree +	0.75 V Per Cell (Max)	2.1 (Approximate)

4.6 COST CALCULATION:

Table III: Cost Calculation

SL No	Equipment Name	Quantity	Price
1	ESP 32	1 pcs	780 TK
2	Voltage Sensor	1 pcs	250 TK
3	Current Sensor	1 pcs	380 TK

4	Relay	1 pcs	85 TK
5	Thermo Electric Converter(Peltier)	3 pcs	1200 TK
6	LCD DisplayI2C	1 pcs	550 TK
7	Bread Board	1 pcs	80 TK
8	PVC Board	2 Feet	280 TK
9	Charge Controller	1 pcs	180 TK
10	Battery	2 pcs	300 TK
11	Load	1 pcs	50 TK
12	Furnace	1 pcs	1100 TK
13	DC Motor	1 Pcs	120 TK
14	Motor Driver	1 Pcs	220 TK
15	Others		1500 TK
		Total	6735 TK

4.7 ADVANTAGES & DISADVANTAGES USED OF THIS PROJECT:

Advantages of Design Development Of Thermal Energy To Electrical Generation System

1. **Energy Recovery from Waste Heat:**
    - The system efficiently captures waste heat from industrial processes or natural sources, transforming it into useful electrical energy, thereby reducing energy wastage.
2. **Eco-Friendly and Sustainable:**
    - As it utilizes thermal energy, which is often wasted, the system supports sustainable energy practices, reducing reliance on fossil fuels and minimizing carbon emissions.
3. **Scalable for Various Applications:**
    - The system can be adapted for both small-scale and large-scale applications, such as remote power generation, microgrids, or supplementing energy needs in isolated locations.

4. **Minimal Moving Parts:**
    - With thermoelectric generators (TEGs) being solid-state devices, the system has fewer mechanical components, leading to low maintenance costs and a longer lifespan.
5. **Silent Operation:**
    - The system operates without mechanical noise, making it ideal for sensitive environments, including hospitals, research facilities, or residential areas.
6. **Operational Flexibility:**
    - It can work in diverse environments, including remote areas, and can harness various heat sources, such as solar thermal, geothermal, or exhaust heat.

Disadvantages of Design Development Of Thermal Energy To Electrical Generation System

1. **Low Conversion Efficiency:**
    - Thermoelectric generators typically have limited efficiency, converting only a small fraction of the input heat into electricity, which can limit overall energy yield.
2. **High Initial Cost:**
    - Quality thermoelectric materials and heat management components can be expensive, increasing the initial setup cost of the system.
3. **Heat Loss Challenges:**
    - Significant heat losses may occur during operation, particularly in systems with poor insulation or ineffective heat exchangers, affecting performance.
4. **Performance Dependence on Temperature Gradient:**
    - The system’s efficiency is highly dependent on maintaining a substantial temperature difference, which may be challenging under varying environmental conditions.
5. **Limited Power Output for Larger Applications:**
    - While effective for small-scale energy needs, the system may struggle to generate sufficient power for larger industrial or grid-scale applications.
6. **Material Degradation Over Time:**
    - Some thermoelectric materials may degrade after prolonged exposure to high temperatures, reducing the system's efficiency and lifespan.

CHAPTER 5: CONCLUSION AND FUTURE RECOMMENDATION

5.1 CONCLUSION

The design and development of the thermal energy to electrical generation system demonstrate the potential of harnessing waste or naturally occurring thermal energy for sustainable power generation. Through careful integration of thermoelectric technology and heat management components, the project highlights how temperature differentials can be converted into electrical energy. Despite challenges such as low conversion efficiency and sensitivity to environmental conditions, the system offers a promising solution for small-scale energy needs and remote applications. The results indicate that while the system is most effective when there is a significant temperature gradient, improvements in materials and design could enhance its efficiency in the future. This project serves as a foundation for further research, particularly in optimizing heat management, improving insulation, and exploring advanced thermoelectric materials to reduce costs and increase energy output. In addition to contributing to the field of renewable energy, the project provides insights into practical applications such as waste heat recovery and microgrid support, making it relevant in the context of sustainable energy solutions. With further development, the system can evolve into a valuable tool for addressing energy challenges, promoting energy conservation, and reducing carbon footprints.

In conclusion, while the thermal-to-electrical generation system has limitations, it holds significant potential as a supplemental energy source. It opens opportunities for future advancements in renewable energy technologies, driving progress toward more efficient, eco-friendly, and sustainable power generation solutions.

5.2 FUTURE RECOMMENDATION

- Adding AI with the system for low consumption of electricity.
- Update app security.
- Adding more watt solar panel.

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APPENDIX

The code for the Project:

```
#include "Wire.h"
   #include <LiquidCrystal_I2C.h>
   #include <WiFi.h>

   #define BLYNK_PRINT Serial
      #include <BlynkSimpleEsp32.h>
        #define INPUT_VOLTAGE_SENSE_PIN 34
   #define INPUT_CURRENT_SENSE_PIN 35
      LiquidCrystal_I2C lcd(0x27,16,2);
      // unsigned long last_time =0;
  //  unsigned long current_time =0;
  //  float power =0 ; // Power in Watt
    //float energy =0 ; // Emergy in Watt-Hour
  //  float tempC=0; // temperaure in Celcius
    //float tempF = 0; temperature in F
   // float saving=0; // cost saving
      int light1=23;
int light=26;
   int l= 0;
int f= 0;
 char auth[] = "UvkpNmHmpcU7oFohdbCQ_n8MHVKLlomO";
char ssid[] = "iot1";
char pass[] = "iot12345";
  BLYNK_WRITE(V3)
{
  int f = param.asInt(); // parameter as int
  if(f == HIGH)
  {
    digitalWrite(light,HIGH);
```

```
   Serial.println("D0 High");
   delay(10);
   }
   if(f == LOW)
  {
   digitalWrite(light,LOW);
   Serial.println("D0 Low");
   delay(10);
   }
}
BLYNK_WRITE(V4)
{
  int l = param.asInt(); // parameter as int
  if(l == HIGH)
  {
   digitalWrite(light1,HIGH);
   Serial.println("D1 High");
   delay(10);
   }
   if(l == LOW)
  {
   digitalWrite(light1,LOW);
   Serial.println("D1 Low");
   delay(10);
   }
}

//=========================                Setup                Function
================================================
void setup() {
  Serial.begin(115200);
  pinMode(light1, OUTPUT);
pinMode(light, OUTPUT);
digitalWrite(light,LOW);
```

```
digitalWrite(light1,LOW);
  Blynk.begin(auth, ssid, pass, "blynk.cloud", 80);
 Wire.begin();
  lcd.begin();
  lcd.backlight();
  pinMode(INPUT_VOLTAGE_SENSE_PIN, INPUT);
  pinMode(INPUT_CURRENT_SENSE_PIN, INPUT);
}
void loop()
{

  // read voltage and current
  float  voltage1  =  (((float)analogRead(INPUT_VOLTAGE_SENSE_PIN)  /  4096  *  18.5  *
28205 / 27000 ));



Serial.println(analogRead(INPUT_CURRENT_SENSE_PIN)*(3.3/4095));
  float ACSValue = 0.0, Samples = 0.0, AvgACS = 0.0, BaseVol = 1.47; //Change BaseVol as
per your reading in the first step.
  for (int x = 0; x < 500; x++) { //This would take 500 Samples
    ACSValue = analogRead(INPUT_CURRENT_SENSE_PIN);
    Samples = Samples + ACSValue;
    delay (3);
  }
  AvgACS = Samples/500;
  float amp = ((((AvgACS) * (3.3 / 4095.0)) - BaseVol ) / 0.066 );



 Serial.print("Voltage1: ");
  Serial.println(voltage1);
delay(500);

Serial.print("Current1: ");
  Serial.println(amp);
```

```
  Serial.println(ACSValue);
  delay(500);
  // lcd.setCursor(0,1);

  //lcd.print(analogRead(INPUT_CURRENT_SENSE_PIN)*(3.3/4095));

 if (amp<0.16){
   Blynk.virtualWrite(V1, 0 ); // virtual pin 1
lcd.setCursor(0,0);
  lcd.print("A:");
   lcd.print("0000");
   lcd.print("A");
  delay(500);}

   if (amp>0.16)
{

  Blynk.virtualWrite(V1, amp ); // virtual pin 1
lcd.setCursor(0,0);
  lcd.print("A:");
   lcd.print(amp);
   lcd.print("A");
  delay(500);
   lcd.setCursor(0,1);
   Blynk.virtualWrite(V2, "Charging OK");
  lcd.print("Charging OK");
  delay(100);
   }
  lcd.setCursor(8,0);
  lcd.print("V:");
   lcd.print(voltage1);
   lcd.print(" V");
delay(100);
   Blynk.run();     Blynk.virtualWrite(V0, voltage1 ); // virtual pin 0  }
```