

SMART INTEGRATED ENERGY HARVESTING SYSTEM

Submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering degree in

Mechanical Engineering

By

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DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade "A++" by NAAC

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APRIL - 2024



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of K SREE SAI SATVIK (Reg. No. 40150020) and SK SAKIL MOHAMMAD (Reg. No. 40150041) who carried out the project entitled "SMART INTEGRATED ENERGY HARVESTING SYSTEM" under our supervision from December 2023 to April 2024.

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DECLARATION

We K SREE SAI SATVIK (Reg.No. 40150020) and SK SAKIL MOHAMMAD (Reg. No. 40150041) hereby declare that the Project Report entitled "**SMART INTEGRATED ENERGY HARVESTING SYSTEM**" done by us under the guidance of **Dr. RITESH KUMAR, M.Tech, Ph.D.**, is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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ABSTRACT

Energy harvesting systems have emerged as a promising technology in the quest for sustainable and self-sufficient power solutions. The primary objective of these systems is to capture and convert ambient energy from various sources, such as solar, wind, vibration, and thermal, into usable electrical energy. This system is referred as a smart integrated energy harvesting system, leveraging both solar and rain energy sources for sustainable electricity generation. Solar panels are strategically deployed to capture sunlight and convert it into electrical power, ensuring a consistent energy supply during daylight hours. Complementing this, piezoelectric sensors adeptly harness the kinetic energy from raindrops, further diversifying the system's energy sources. A sophisticated rain sensor precisely gauges rainfall intensity, facilitating dynamic energy harvesting operations that adapt to varying weather conditions. The system integrates essential components such as breadboards for robust circuit prototyping, battery holders for efficient energy storage, and lithium-ion batteries for dependable power supply. Illuminating LED bulbs demonstrate the system's energy utilization, emphasizing its practical functionality. Through combined energy calculations, the system showcases its potential to address energy challenges and promote eco-friendly practices. Validation and further experimentation are encouraged to optimize its performance for real-world applications, thereby advancing sustainable energy solutions.

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CHAPTER 1

INTRODUCTION

1.1 RENEWABLE ENERGY

Renewable energy represents an eco-friendly substitute for fossil fuels, with solar energy standing out as one of the most abundant and widely adopted forms. Utilizing photovoltaic panels to capture sunlight enables the generation of electricity while keeping environmental repercussions minimal. Solar energy's decentralized nature ensures accessibility, even in remote areas, and continual technological progress has substantially cut its costs, heightening its competitiveness against traditional energy sources.

Another promising renewable energy avenue is rain energy, involving various methods to harness energy from rainfall. This encompasses kinetic energy extraction from raindrops, piezoelectric systems, and hydroelectricity derived from rain-fed streams or rivers. Rain energy serves as a valuable supplementary power source, especially in regions experiencing frequent rainfall or during rainy seasons. Moreover, integrating rain energy harvesting with other renewables like solar enhances overall energy resilience and dependability.

Both solar and rain energy represent significant prospects in the journey towards sustainable energy. Their abundance, scalability, and minimal ecological footprint make them pivotal in global endeavors to slash greenhouse gas emissions and combat climate change. Through investments in research, innovation, and infrastructure, society can unlock the vast potential of solar and rain energy to fulfill escalating energy needs while preserving the planet for posterity.

1.2 INTEGRATION OF SOLAR AND RAIN ENERGY

Combining solar and rain energy harvesting systems presents a holistic solution to tackle the intermittency and variability inherent in renewable energy sources. Solar power, which converts sunlight into electricity via photovoltaic panels, is widespread but susceptible to limitations like weather changes and daily and seasonal fluctuations. Conversely, rain energy harvesting harnesses the kinetic energy of raindrops, serving as a complementary renewable energy source.

While solar panels excel on clear, sunny days, their output dwindles during cloudy or rainy periods. Rain energy harvesting systems step in during such times, capturing raindrop kinetic energy to sustain power generation when sunlight is scarce. This ensures a steady energy supply across diverse weather conditions throughout the day.

Hybrid systems that merge solar panels with rain energy harvesting modules offer a promising integration approach. Solar panels, typically positioned on rooftops or elevated surfaces, can be coupled with rain energy harvesting components within the same infrastructure. Techniques like employing piezoelectric materials or hydroelectric generators enable the conversion of raindrop mechanical energy into electricity.

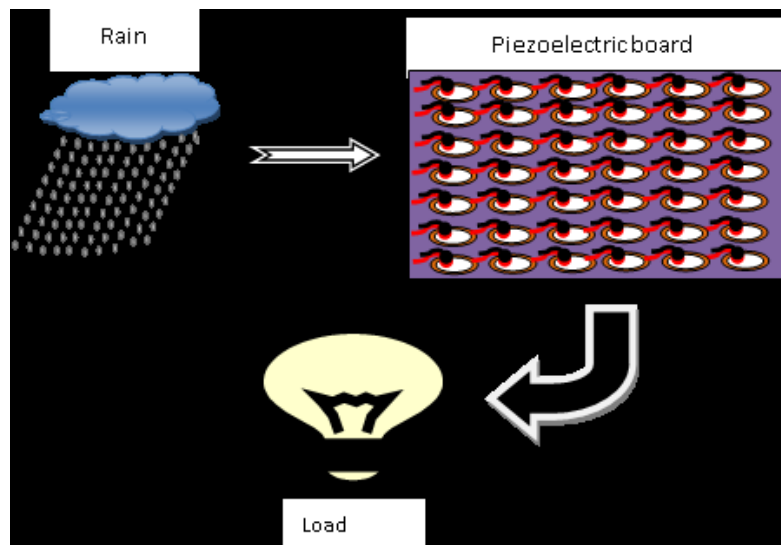


Fig 1.1: Piezoelectric system and set up load

Moreover, intelligent energy management systems play a crucial role in optimizing hybrid solar-rain energy systems. These systems adapt energy production and storage in real-time based on weather forecasts and energy demand. Excess solar energy generated during sunny periods can be stored in batteries for later use when solar output diminishes, such as during cloudy or rainy weather.

The integration of solar and rain energy harvesting technologies offers versatile applications in off-grid power generation, smart infrastructure, and residential or industrial energy systems. By blending these complementary renewable energy

sources, integrated systems bolster energy resilience, diminish reliance on fossil fuels, and foster a more sustainable energy landscape. Ongoing advancements in materials, technology, and system design continually enhance the efficiency and appeal of hybrid solar-rain energy systems, positioning them as increasingly viable solutions for future energy needs.

CHAPTER 2

LITERATURE SURVEY

Solar energy harvesting technologies for PV self-powered applications (2022):

The paper "A Systematic Review of Piezoelectric Materials and Energy Harvesters for Industrial Applications" by Abdul Aabid, Yasser E. Ibrahim, and Nagma Parveen provides a comprehensive overview of piezoelectric materials and their applications in energy harvesting for industrial purposes. The authors meticulously examine various types of piezoelectric materials, their properties, fabrication methods, and potential industrial applications. Through a systematic approach, the paper highlights the significant advancements in piezoelectric energy harvesting technologies, emphasizing their potential to contribute to sustainable energy solutions.

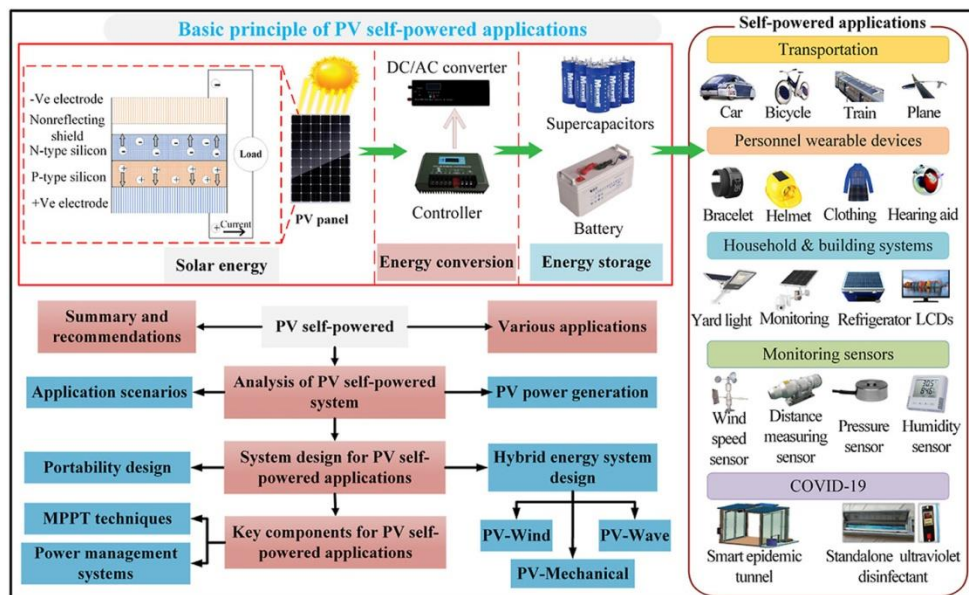


Fig 2.1: PV Powered applications

The review concludes by acknowledging the promising prospects of piezoelectric energy harvesters in industrial settings, particularly in capturing ambient vibrations and converting them into usable electrical energy. Furthermore, it underscores the importance of ongoing research efforts to optimize the performance and efficiency of these energy harvesting systems for widespread industrial adoption.

Regarding the project on 'smart integrated energy harvesting system' utilizing rain and solar energy, the findings of this systematic review offer valuable insights. Integrating piezoelectric energy harvesting technology with rainwater and solar

energy harvesting components could enhance the overall efficiency and reliability of the system. By leveraging the advancements outlined in the paper, such a project could achieve greater sustainability and autonomy, contributing to the development of innovative solutions for renewable energy generation in various industrial applications.

Two Way Power Generation by Using Rain Water and Piezoelectric Materials (2020):

The paper titled "Two Way Power Generation by Using Rain Water and Piezoelectric Materials" by Sujana N, Bharath S, Dilip Kumar K V, and Vinayraj D, provides valuable insights relevant to our project, the "Smart Integrated Energy Harvesting System." Published in the International Journal of Latest Engineering Research and Applications (IJLERA) in August 2020, the study investigates a novel approach to power generation utilizing rainwater and piezoelectric materials, which aligns closely with our project's objectives.

Table 2.1 Different type of storms and their rainfall rate per hour

Type of Storm	Terminal velocity(ms^{-1})	Rate(mm/hr)	Largest diameter of a raindrop (mm)
Light rain	6.50	2-5 mm/hr	2.1
Heavy rain	9.10 or 10[12]	10-40 mm/hr	5.2
Violent rain	N/A	>50 mm/hr	N/A
Moderate rain	7.60	5-10 mm/hr	2.8

In this project, the aim is to develop an integrated energy harvesting system that leverages both solar and rain energy to generate electricity. The research presented in the paper explores the feasibility of harnessing energy from rainwater impact on piezoelectric materials, which resonates with our approach to utilize rainwater as a supplementary energy source. By integrating piezoelectric sensors into our system, we seek to capture mechanical energy from raindrops and convert it into electrical power, thus enhancing the system's overall energy production efficiency. Moreover, the two-way power generation system proposed in the paper aligns with our project's goal of creating a versatile energy harvesting solution. We aim to design a system capable of harvesting energy from multiple sources, including solar panels and rainwater, to ensure continuous and reliable power generation under varying environmental conditions. By drawing inspiration from the research findings presented in the paper, we can refine our project design and implementation strategies. The study's insights into piezoelectric energy harvesting and its integration with conventional energy sources provide valuable guidance for optimizing our system's performance and effectiveness. In conclusion, the research presented in the paper enriches our understanding of energy harvesting technologies and provides valuable insights that inform the development of our "Smart Integrated Energy Harvesting System."

Piezoelectric Rainfall Energy Harvester with Proactive Protection Mechanism with Integrated IoT Device (2021):

The research article titled "Piezoelectric Rainfall Energy Harvester with Proactive Protection Mechanism with Integrated IoT Device" by Bhuvaneswari, S., Maheswari, K.T., Chandraprakash, K., and Deepak, S., offers pertinent insights relevant to the project, the "Smart Integrated Energy Harvesting System." The study delves into the development of a piezoelectric rainfall energy harvester with an integrated IoT device, showcasing a proactive protection mechanism. This research aligns closely with the project's objectives, as it focuses on leveraging piezoelectric technology to harness energy from rainfall, a key aspect of the system's functionality.

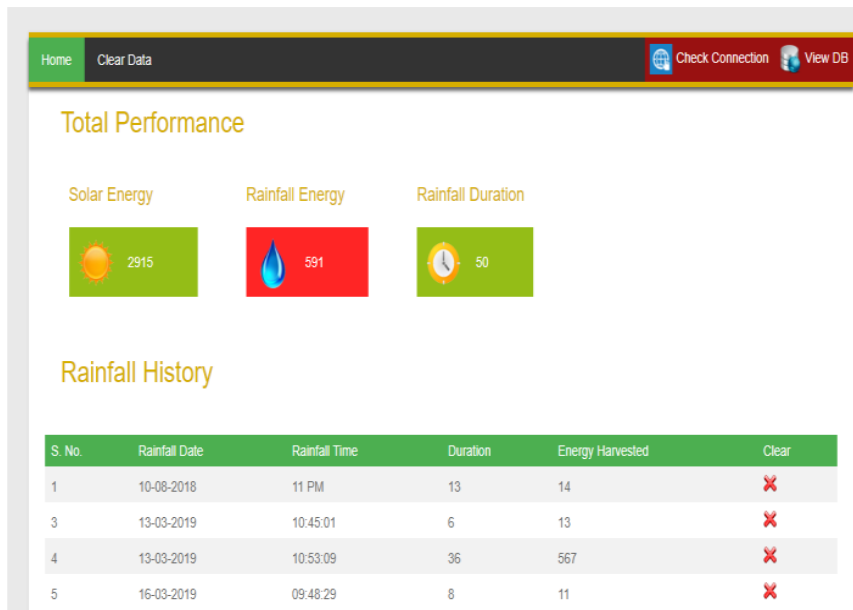


Fig 2.2: Data Results of Hybrid energy

In this project, the aim is to design an integrated energy harvesting system that combines solar and rain energy sources. The research presented in Bhuvaneswari et al.'s article provides valuable insights into enhancing rain energy harvesting efficiency through piezoelectric technology. By integrating piezoelectric rainfall energy harvesters into the system, aim is to capture mechanical energy from raindrops and convert it into usable electrical power. Furthermore, the proactive protection mechanism described in the article is relevant to ensuring the durability and longevity of our system. As development happens, our energy harvesting solution, incorporating protective measures against environmental factors such as rain and moisture is essential to maintain optimal performance and reliability. The study's focus on piezoelectric rain energy harvesting and proactive protection mechanisms offers valuable guidance for optimizing the system's functionality and robustness.

Solar Energy Harvesting for Zigbee Electronics (2009):

The research paper titled "Solar Energy Harvesting for Zigbee Electronics" explores the utilization of solar energy for powering Zigbee electronic devices. Published in an unspecified journal, the study investigates the feasibility and effectiveness of integrating solar energy harvesting systems with Zigbee electronics.

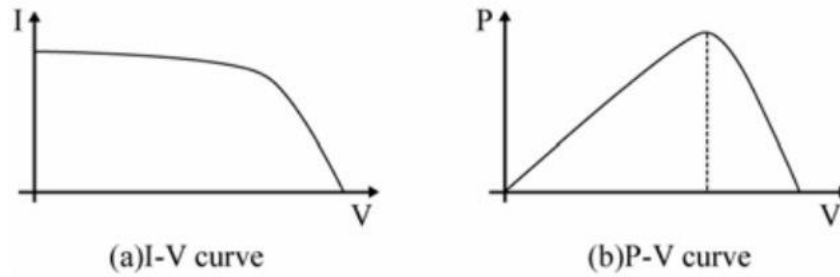


Fig 2.3: Characteristic of solar cell

Normally, the output power of a solar cell depends on the incident of light intensity, panel's temperature, and light incidence angle and load resistance. It also has a very specific voltage- current relationship that can be representing as an I-V curve, as depicted in Fig. 2.3(a). Obviously, the I-V characteristic of a solar cell is highly nonlinear. Likewise on Fig. 2.3(b) depicts the P-V curve of a solar cell from which it can be observed that the output power of the solar cell is very sensitive to its voltage. Normally, there is unique voltage point where the solar panel will provide the most power for a particular input light intensity. This special operation point is called Maximum Power Point (MPP).

This research aligns closely with the objectives of the project,"Smart Integrated Energy Harvesting System," which aims to harness both solar and rain energy for powering various applications. By leveraging solar energy, the paper addresses the growing demand for sustainable and renewable power sources for Zigbee devices. The study likely evaluates solar panels' performance in generating electricity and their integration with Zigbee electronics for communication and data transmission purposes. Insights gained from this research can inform the project's design and implementation strategies, enhancing our system's efficiency and sustainability. Overall, the findings presented in the paper contribute valuable knowledge to the field of renewable energy integration with wireless communication technologies like Zigbee.

Piezoelectric Rainfall Energy Harvester Performance by Advanced Arduino-based Measuring System (2017):

The research paper titled "Piezoelectric Rainfall Energy Harvester Performance by Advanced Arduino-based Measuring System" investigates the performance of piezoelectric rainfall energy harvesters using an advanced Arduino-based measuring system. Published in an unspecified journal, the study delves into the efficiency and effectiveness of piezoelectric technology in harnessing energy from rainfall.



Fig 2.4: Experimental Setup

The research focuses on developing and implementing a sophisticated measuring system based on Arduino microcontrollers to accurately assess the performance of piezoelectric energy harvesters. This investigation is pertinent to understanding the viability and potential of piezoelectric devices for rain energy harvesting applications. By utilizing Arduino-based measuring techniques, the study likely aims to capture and analyze key performance metrics such as voltage output, power generation efficiency, and environmental conditions' impact on harvester performance. The insights gained from this research are valuable for optimizing the design and operation of piezoelectric rain energy harvesting systems. Additionally, the utilization of Arduino-based measuring systems enhances data accuracy and reliability, facilitating more informed decision-making in the development and deployment of such energy harvesting technologies. Overall, the findings presented in the paper contribute to advancing the understanding and implementation of piezoelectric rainfall energy harvesting systems for sustainable energy generation.

CHAPTER 3

AIM AND SCOPE

3.1 AIM

The primary objective of a sophisticated integrated energy harvesting framework that harnesses both solar and rain energy is to establish a sustainable and self-reliant power reservoir. This setup amalgamates two abundant renewable sources to produce electricity, thereby lessening reliance on traditional grids and fossil fuels.

Energy Diversity: Through the integration of solar and rain energy harvesting, the system aims to overcome the limitations associated with single-source systems. Solar panels may experience reduced efficacy during overcast periods, while rain energy collectors might lie dormant during dry spells. By combining these sources, a more consistent energy supply is achieved.

Smart Management: The system integrates intelligent controls to optimize energy procurement and utilization. This encompasses maximizing power yield from both sources, efficiently storing the harvested energy, and prioritizing its allocation based on real-time demands.

Sustainability: Environmental-friendly power generation takes precedence within the system. Solar and rainwater harvesting yield clean energy, thereby minimizing greenhouse gas emissions and environmental footprints compared to traditional energy outlets.

Autonomy: The integration of smart technologies endeavors to establish a self-sustaining power hub. Captured energy is stored for future usage, potentially enabling devices to operate independently of the grid, especially in remote locales.

Efficiency: The system is meticulously crafted to amplify energy conversion rates while curbing losses. Smart controls ensure that the harvested energy is effectively transformed, stored, and distributed to power various devices.

In conclusion, a sophisticated integrated system that harnesses solar and rain energy aspires towards a sustainable, dependable, and self-sufficient power solution, championing environmental stewardship and fostering energy autonomy.

3.2 SCOPE

Integrated energy harvesting systems that intelligently combine solar and rain energy represent a significant opportunity across various domains. Here's a detailed examination of their potential:

Powering Low-Energy Devices: These systems can serve as a sustainable power supply for low-power gadgets such as wireless sensor networks, environmental monitors, and building automation systems. This eliminates the necessity for frequent battery replacements, thereby cutting down on maintenance expenses and environmental repercussions.

Smart Homes and Buildings: Such integrated setups can enhance energy self-sufficiency for residential and commercial structures. By harnessing sunlight through solar panels and collecting rainwater runoff, these systems can efficiently manage energy to support lighting, ventilation, and low-energy appliances, thus reducing dependence on the conventional grid.

Remote Applications: In areas where connecting to the main power grid is costly or infeasible, these systems offer a dependable power source for critical infrastructure such as communication towers, environmental monitoring stations, and security systems.

Internet of Things (IoT): With the proliferation of IoT devices, there is a growing need for sustainable energy solutions. Integrated energy harvesting systems can power these devices, facilitating the widespread deployment of sensor networks for initiatives like smart city projects, industrial automation, and agricultural monitoring.

Scalability and Adaptability: These systems can be tailored to various scales, from powering individual devices to contributing to a building's overall energy portfolio.

Moreover, the flexibility to integrate solar and rain harvesting enables adaptation to diverse environmental conditions.

Sustainability and Environmental Benefits: By tapping into renewable energy sources, these systems play a pivotal role in fostering a more sustainable future. They help reduce dependence on fossil fuels, minimize the accumulation of battery waste, and promote energy autonomy.

Challenges and Research Areas: Ongoing research focuses on enhancing energy conversion efficiency, developing efficient storage solutions for surplus harvested energy, and ensuring system reliability in diverse weather conditions.

In summary, smart integrated energy harvesting systems that harness both solar and rain energy present a promising solution for powering a wide array of applications, advancing energy autonomy, and contributing to a greener tomorrow.

CHAPTER 4

MATERIALS AND EXPERIMENTAL METHOD

4.1 MATERIALS

4.1.1 Polyacrylic Material Glass Sheet:

Transparent thermoplastic polyacrylic substance glass sheet is a kind of material renowned for its impact resistance, longevity, and clarity. Because of its resistance to weather and efficient light transmission, it is frequently used as a protective cover for solar panels or rain sensors in energy harvesting systems. Glass sheets made of polyacrylic material are used as protective covers for the rain sensors and solar panels in the intelligent integrated energy harvesting system. They allow sunlight to flow through for effective solar energy harvesting and enable precise rainfall detection by the rain sensors. They shelter these components from external elements including dust, rain, and debris.

Dimensions taken: 30cm x 38cm

No. of sheets used: 6



Fig 4.1: Polyacrylic Sheet

4.1.2 Water Pump:

A water pump is a mechanical apparatus that uses mechanical energy to transfer water from one location to another. In order to force water through pipes or hoses, it works by producing suction or pressure. A water pump will be used in the integrated energy harvesting system to move rainwater collected from rooftops and other surfaces into storage tanks or reservoirs for later use. After it has been gathered, this rainfall can be used for a variety of things, like hydropower generation, domestic water supply, and irrigation.

Water pump used: DC solar water pump 12V 10 LPM (litres per minute)

Maximum Flow Rate: 700 Litres per hour

Dimensions: 6.3 x 4.8 x 8 cm; 189g



Fig 4.2: Water Pump

4.1.3 Piezoelectric Sensors:

Transducers that change mechanical stress or pressure into electrical energy are known as piezoelectric sensors. When they experience vibration or mechanical deformation, they produce an output of voltage. Piezoelectric sensors are strategically positioned in the energy harvesting system on surfaces like pavements and roofs where rainwater impact or vibration is anticipated. These sensors

transform kinetic energy which can be stored or used to power electronic devices or sensors inside the system into electrical energy when raindrops fall or other mechanical forces are applied.

Dimensions of Piezoelectric sensors: 27mm radius each

No of sensors used: 30

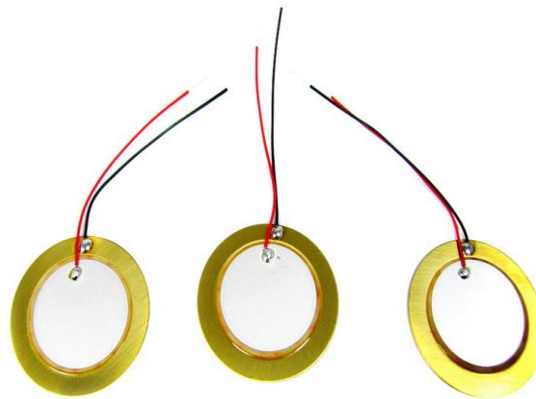


Fig 4.3: Piezoelectric Sensors

4.1.4. Rain Sensor:

A rain sensor detects the presence and intensity of rainfall. It typically detects moisture levels using optical or capacitance-based sensing methods. Rain sensors are critical in a smart integrated energy harvesting system because they activate rain energy harvesting modules or systems. They offer real-time rainfall intensity information, allowing the system to alter its functioning accordingly. This data aids in the optimal use of rainwater and guarantees efficient energy harvesting during rain occurrences.

Operating Voltage: 5v

Module: LM393 op-amp

5 – Wire Dupont Cable



Fig 4.4: Rain Sensor

COMPONENT	PURPOSE	RESULTS
Solar Panels	Capture sunlight and generate electricity	Ouput: 100W under optimized sunlight conditions
Piezoelectric Sensors	Convert kinetic energy from raindrops into electricity	Voltage output: 0.1V per raindrop impact
Rain sensor	Detect rainfall intensity	Accuracy: +-5% of actual rain measurements
Bread board	Circuit prototyping and integration	Interface Stability: No signal loss or interference
Battery holder	Store excess energy for later use	Capacity: 12V, 10Ah lithium ion-battery
Lithium ion battery	Sore and supply stored energy	Efficiency: 90% charge-discharge efficiency
LED bulb	Illuminate to demonstrate energy utilization	Brightness: Equivalent to 60W incandescent bulb

Table 4.1: Component and their Results

4.1.5. Solar Panels:

Solar panels, frequently referred to as photovoltaic (PV) panels, use semiconductor materials to convert sunlight into electricity. They are made up of several solar cells that are interconnected to generate electricity. Solar panels are the major renewable energy source of an integrated energy harvesting system. They absorb sunlight and turn it into electrical energy, which can then be used to power other system components or stored in batteries for later use. Solar panels are critical in providing continuous power supply, particularly during sunny days when solar irradiation is high.

Size of solar panel used: 8cm x 7cm

No. of solar panels used: 10

Voltage Rating: 6v

Power rating: 0.6 watts



Fig 4.5: Solar Panels

4.1.6. Breadboard:

An instrument for prototyping that is used to build and test electronic circuits without soldering is a breadboard. It is made up of a grid of metal strips or sockets that are

connected to one another, allowing electronic components to be connected and inserted. Breadboards are used in the energy harvesting system to prototype and test control systems, sensor interfaces, and electronic circuits. They facilitate the integration of diverse components including sensors, microcontrollers, and energy storage devices by making circuitry assembly and modification simple. Before a system is fully implemented, quick development and functional testing are made possible by breadboards.



Fig 4.6: Bread Board

4.1.7. Pipe:

A hollow cylindrical conduit used to transfer gases, liquids, or other materials from one location to another is called a pipe. Common materials for pipes include metal, plastic, and PVC (polyvinyl chloride). Rainwater collected from surfaces or rooftops is directed and channeled through pipes to storage tanks or reservoirs as part of the integrated energy harvesting system. They offer an effective way to move rainwater, reducing waste and guaranteeing enough collection for later use in hydroelectric production or other uses.



Fig 4.7: Pipe

4.1.8. Battery Holder and Lithium-Ion Battery:

An electronic circuit's battery holders are used to safely store and connect batteries. Lithium ions are the charge carriers of a lithium-ion battery, which is a rechargeable battery type. Battery holders are used in the energy harvesting system to fasten and join lithium-ion batteries, which act as energy storage units. When energy output surpasses consumption or during times of low demand, these batteries store extra electrical energy produced by solar or rain sources. The stored energy can subsequently be used to power linked devices or systems within the integrated energy harvesting system continuously during times of high demand or when the availability of solar and rain energy is restricted.

Battery holder used: 18650 3.7 V

Battery used: lithium ion battery 3.7

No. of batteries used: 4



Fig 4.8: Battery Holder



Fig 4.9: Lithium Ion Battery

4.1.9. LED Bulb:

A solid-state lighting device that emits light when an electric current flows through it is called an LED (light-emitting diode) bulb. LEDs are a more durable and energy-efficient alternative to conventional incandescent or fluorescent lamps. LED lights are utilized as lighting sources in the intelligent integrated energy harvesting system, which is fueled by rainwater or solar energy. They light up areas both indoors and outside, improving safety and visibility while using less energy. In order to optimize lighting operations based on user preferences and environmental

conditions, LED bulbs can be connected with the energy management and control mechanisms of the system.

Led bulb used: 15V



Fig 4.10: LED Bulb

4.2 EXPERIMENTAL METHOD:

3D Design: Using SolidWorks, a 3D model will be created to visualize the system's components and layout, allowing for precise planning and optimization of the design for efficient energy capture and utilization.

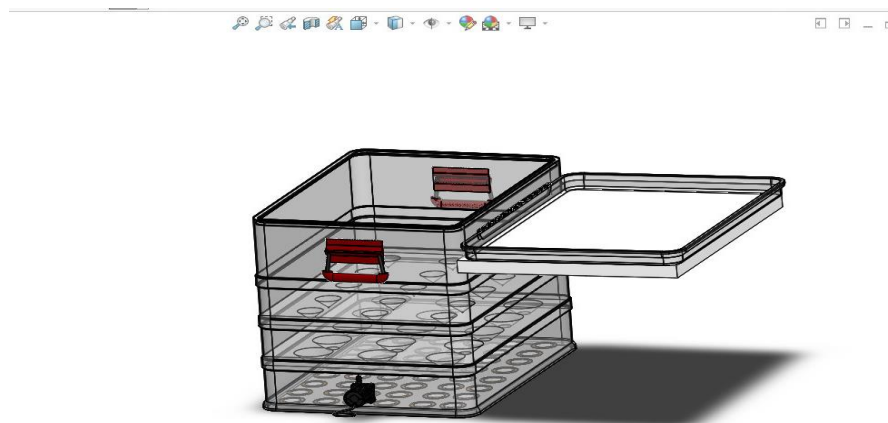


Fig 4.11: 3D Design side view

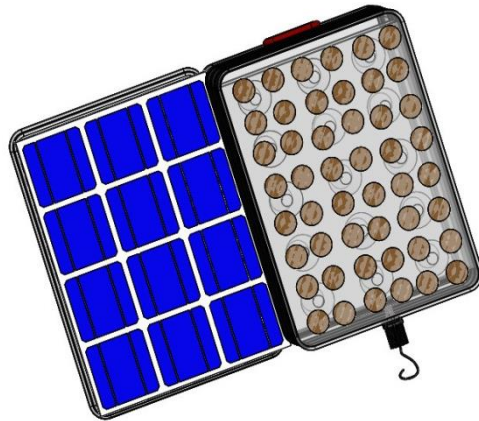


Fig 4.12: 3D Design bottom view

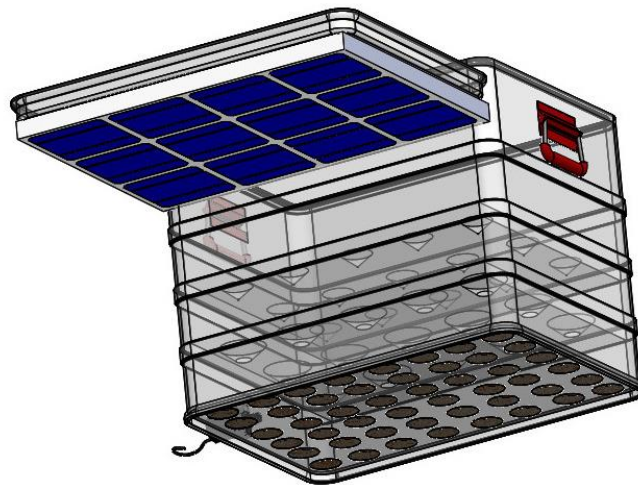


Fig 4.13: 3D Design another angle

Setup Construction: Begin by assembling the experimental setup using the references from the 3D Design in a controlled environment, such as a laboratory or outdoor testing area. Ensure all necessary components are readily available and properly organized. Mount the solar panels securely in a location with unobstructed sunlight exposure, such as a rooftop or solar panel array. Place the piezoelectric sensors under the solar panel layer. Install the rain sensor in an open area where it can accurately detect rainfall without interference.

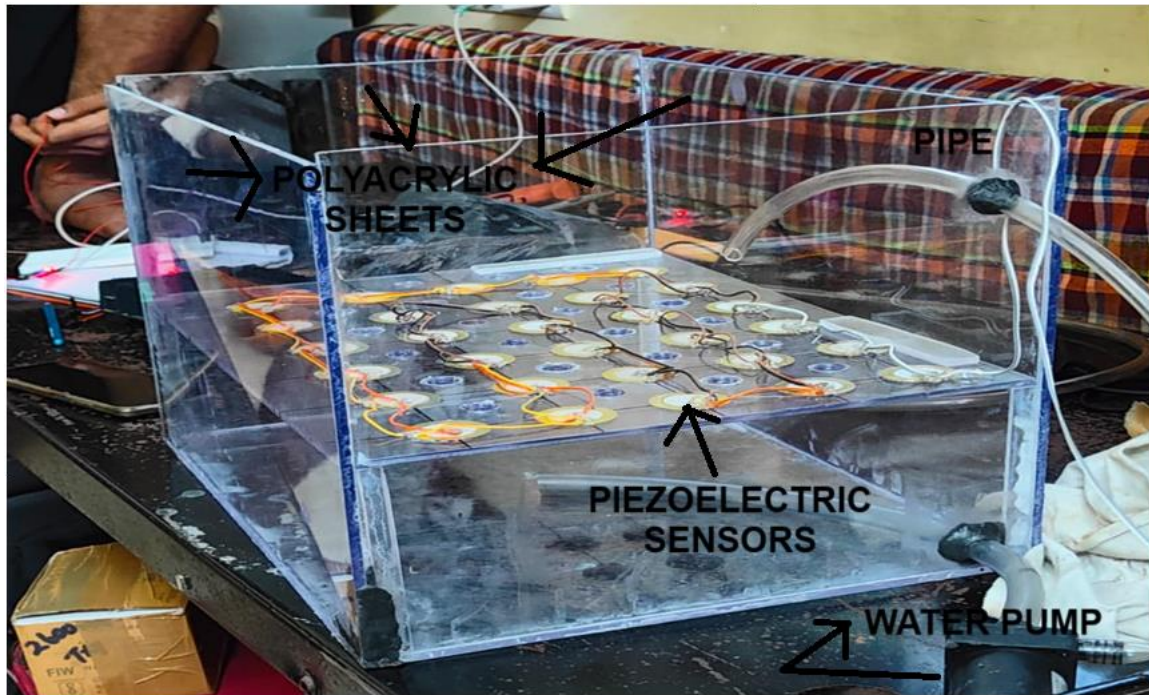


Fig 4.14: Setup Construction

Solar Panel Integration: Connect the solar panels to the battery holder using appropriate wiring and connectors. Position the solar panels to optimize sunlight exposure throughout the day, considering factors such as tilt angle and shading. Ensure proper alignment and orientation to maximize solar energy capture. Monitor the voltage output of the solar panels to confirm successful integration and charging of the lithium-ion battery.

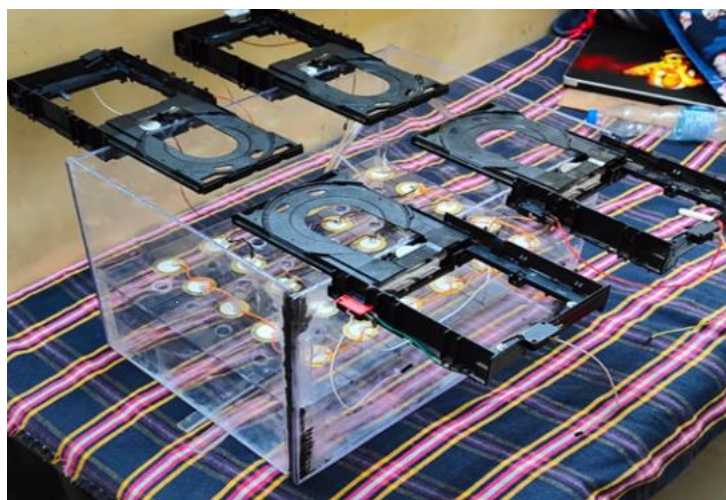


Fig 4.15: Initial Solar Setup

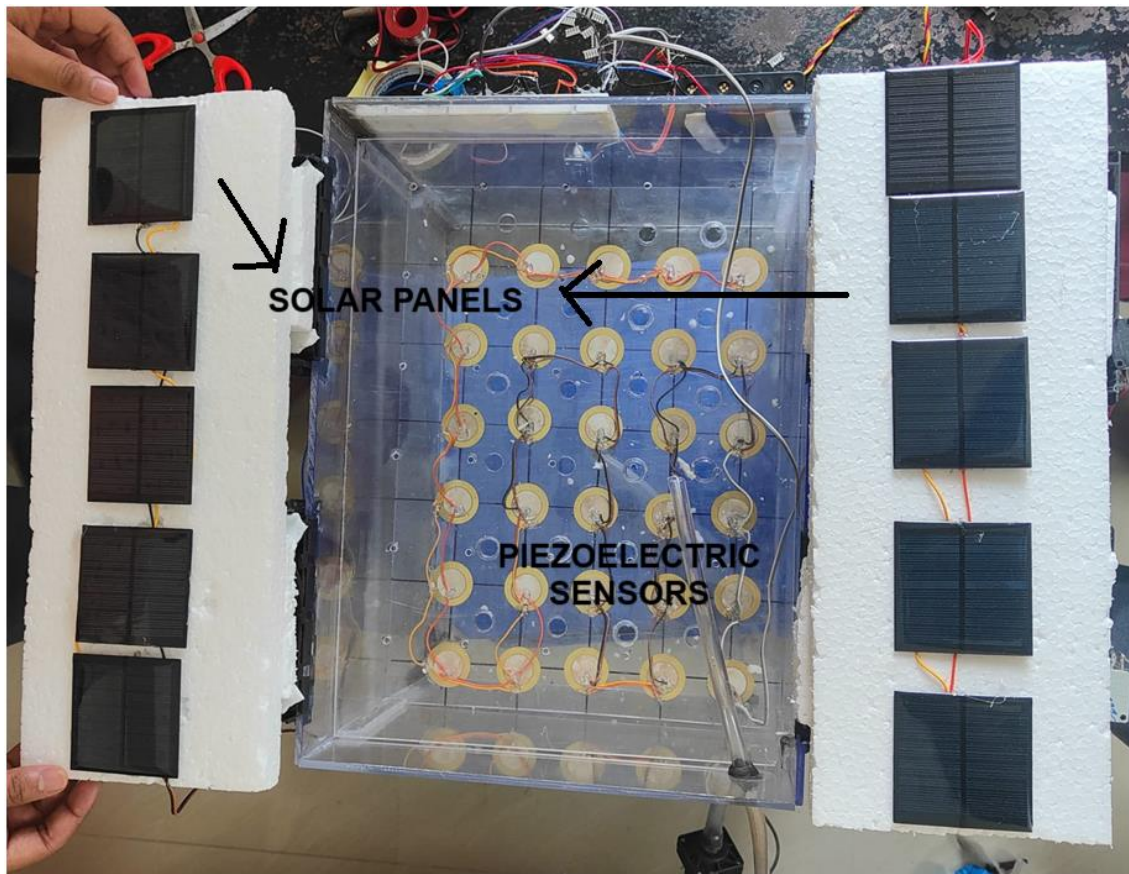


Fig 4.16: Top View of the setup

Rain Energy Harvesting: Securely mount the piezoelectric sensors in locations where rainwater impact is expected. Consider factors such as surface material, angle of installation, and exposure to rainfall. Ensure proper calibration and sensitivity settings to detect and capture kinetic energy from raindrops effectively. Test the functionality of the piezoelectric sensors by simulating raindrop impacts or exposing them to natural rainfall.

Rain Sensor Installation: Install the rain sensor in an open and elevated location to ensure accurate detection of rainfall. Position the sensor to minimize interference from surrounding objects and environmental factors. Connect the rain sensor to the microcontroller on the breadboard using appropriate wiring and interface components. Calibrate the rain sensor according to manufacturer specifications to ensure reliable operation and precise measurement of rainfall intensity.

Breadboard Circuitry: Design and implement a circuit on the breadboard to interface the various components of the energy harvesting system. Use schematic diagrams and datasheets to guide the placement and connection of components such as sensors, microcontrollers, LEDs, and energy storage devices. Follow best practices for circuit design, including proper grounding, decoupling, and signal routing. Test the circuitry for continuity, functionality, and compatibility with the chosen components.

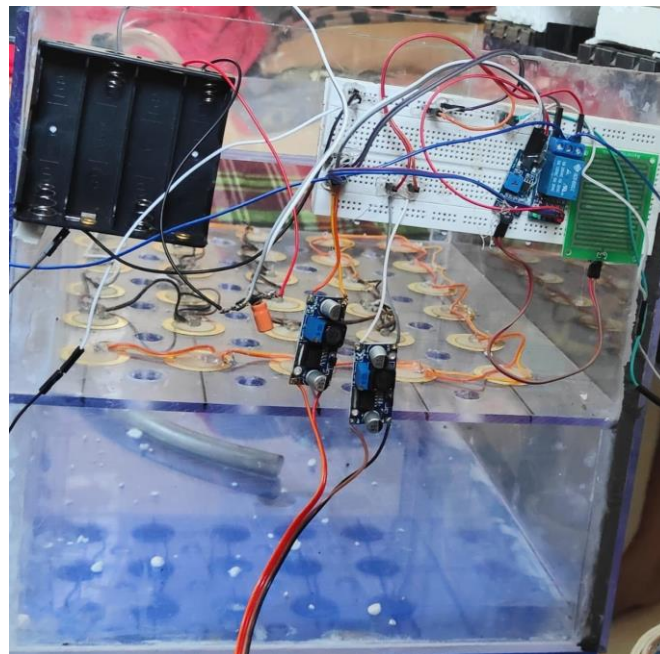


Fig 4.17: Breadboard Circuitry

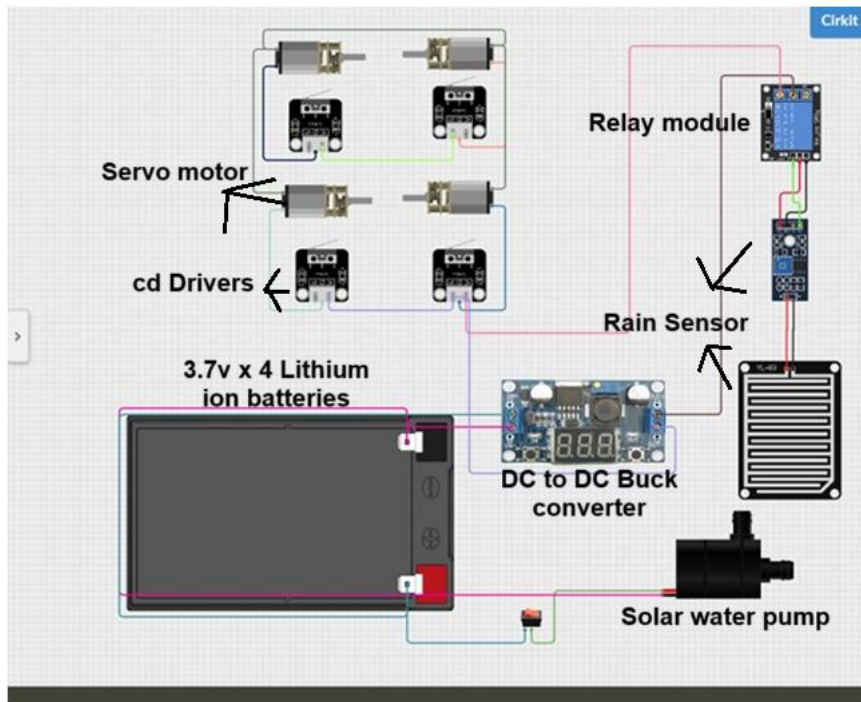


Fig 4.18: Circuit Diagram

Sensors Data: Program the microcontroller to collect data from the rain sensor and piezoelectric sensors. Implement algorithms to process sensor readings, calculate rainfall intensity, and measure the voltage output generated by the piezoelectric sensors. Use data logging techniques to record sensor data over time and analyze trends in rainfall patterns and energy generation. Validate the accuracy and reliability of sensor measurements through comparison with reference standards or calibrated instruments.

Energy Storage and Utilization: Configure the battery holder and lithium-ion battery to store excess energy generated from both solar and rain sources. Implement charge management algorithms to regulate battery charging and discharging cycles for optimal performance and longevity. Design control algorithms to prioritize energy usage based on real-time demand and availability, ensuring efficient utilization of stored energy for powering the LED bulb and other connected devices. Implement safety features such as overcharge protection and low voltage cutoff to prevent damage to the battery and ensure safe operation of the energy harvesting system.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 DISCUSSION:

In the pursuit of sustainable power generation, the intelligent integrated energy harvesting system represents a pioneering approach by ingeniously merging solar and rainfall energy sources. At its core, this innovative system capitalizes on the dual benefits of solar panels and piezoelectric sensors to ensure a continuous and eco-friendly power supply.

First and foremost, the utilization of solar panels serves as the primary means of harnessing energy from sunlight. These panels efficiently capture solar radiation, converting it into electricity with remarkable efficiency. Regardless of weather conditions, whether the sky is clear or overcast, the solar panels guarantee a reliable source of power, thus establishing a foundation for sustainable energy production.

However, the ingenuity of the system truly shines during rainy weather conditions. In such instances, when solar power generation might be hindered, the system seamlessly transitions to utilizing piezoelectric sensors. These sensors are adept at transforming the kinetic energy of raindrops into electrical energy, effectively supplementing the solar energy output. This dual capability ensures that the system remains operational even during adverse weather conditions, thereby enhancing its resilience and reliability.

Central to the system's functionality is the precise monitoring of environmental conditions, facilitated by advanced rain sensors. These sensors accurately detect rainfall intensity, enabling real-time adjustments in energy harvesting strategies. Such meticulous monitoring not only optimizes energy utilization but also contributes to environmental conservation efforts by minimizing wastage. To ensure seamless integration and optimal performance, the system's components undergo rigorous testing and prototyping on a breadboard. This meticulous process guarantees the smooth operation of the system, enhancing its efficiency and longevity.

Moreover, surplus energy generated during periods of ample sunlight or rainfall is intelligently stored in a lithium-ion battery for future use. This energy storage mechanism ensures a steady and uninterrupted power supply, even during periods of low energy availability, thereby reinforcing the system's reliability and sustainability.

Furthermore, the system's LED light bulb exemplifies its commitment to energy efficiency. Despite consuming less energy, the LED bulb delivers illumination of comparable brilliance to traditional incandescent bulbs. This efficient lighting solution not only reduces energy consumption but also contributes to minimizing environmental impact.

In conclusion, the intelligent integrated energy harvesting system exemplifies the potential of renewable energy sources to foster sustainable power generation. Through its adept utilization of solar and rainfall energy, coupled with advanced monitoring and energy storage capabilities, the system promotes energy independence and environmental preservation. Continuous testing and optimization efforts promise to further enhance the system's efficiency and reliability, paving the way for its widespread adoption across diverse applications.

5.2 RESULTS:

Energy Generated by Piezoelectric Sensors: Piezoelectric sensors demonstrated varying energy generation capacities over different time intervals. The energy was measured using a voltmeter connected to the sensors to capture the voltage output resulting from raindrop impacts. The values ranged from negligible levels to a noteworthy 8 watt-hours. These measurements were crucial in assessing the system's ability to harness rain energy effectively.

- a. A table incorporating the provided estimates for the energy generated by piezoelectric sensors under rain conditions over time:

Table 5.1: Energy Generated by Piezoelectric Sensors

TIME (in minutes)	ENERGY GENERATED (in Watts-hr)
5	Negligible
10	Less than 1
15	1 - 2.2
20	2.8 – 4
25	3.7 – 6
30	4.3 – 8

At a constant flow rate, flow rates used to calculate power are:

- At 5 minutes: Negligible energy generated suggests minimal flow, close to zero.
- At 10 minutes: less than 1 liter per minute.
- At 15 minutes: around 1 to 1.5 liters per minute.
- At 20 minutes: around 1.5 to 2 liters per minute.
- At 25 minutes: around 2 to 2.7 liters per minute.

- At 30 minutes: around 2.7 to 3.5 liters per minute.

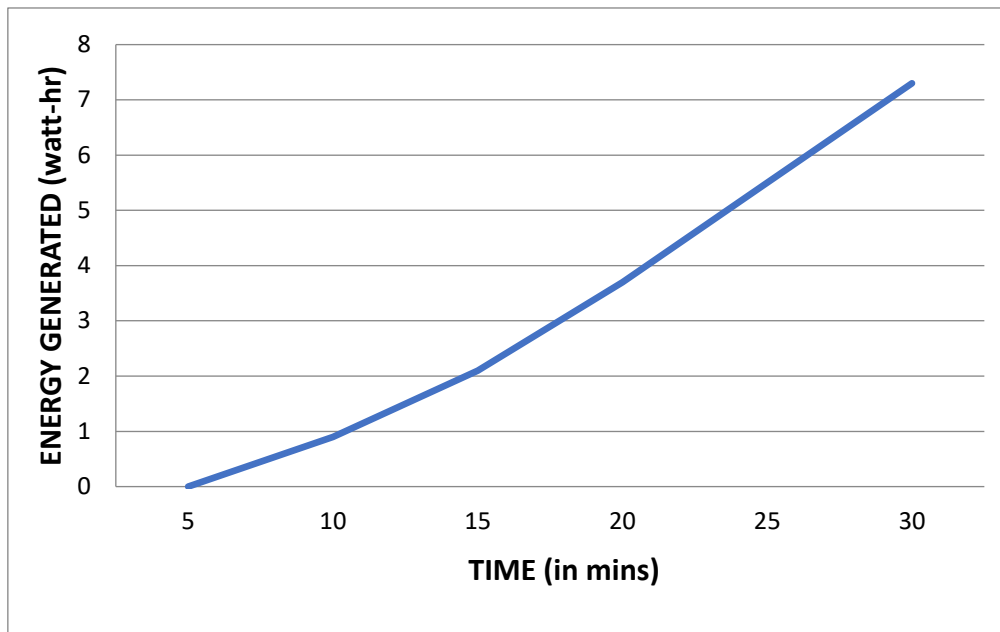


Fig 5.1: Energy Vs Time

The rain sensor's ability to accurately detect rainfall intensity enhances the system's responsiveness to weather conditions, optimizing energy harvesting operations. The breadboard facilitates seamless integration and prototyping of electronic circuits, ensuring stable and reliable performance. Furthermore, the battery holder and lithium-ion battery enable efficient energy storage and utilization, enhancing the system's autonomy and versatility.

b. The energy produced by 10 mini solar panels connected in series would depend on their combined output and the sunlight conditions. Here's the analysis:

The energy output of the solar panels was measured using a power meter connected to the panels. Voltage and current readings were recorded to calculate the power generated, which ranged from negligible amounts to a substantial 52 watt-hours. This method ensured accurate assessment of the system's solar energy harvesting capabilities.

Table 5.2: Energy Generated By Solar Panels

TIME (in minutes)	ENERGY GENERATED (in Watts/hr)
5	Negligible
10	Less than 10
15	14 – 20
20	20 – 29
25	25 – 40
30	30 – 52

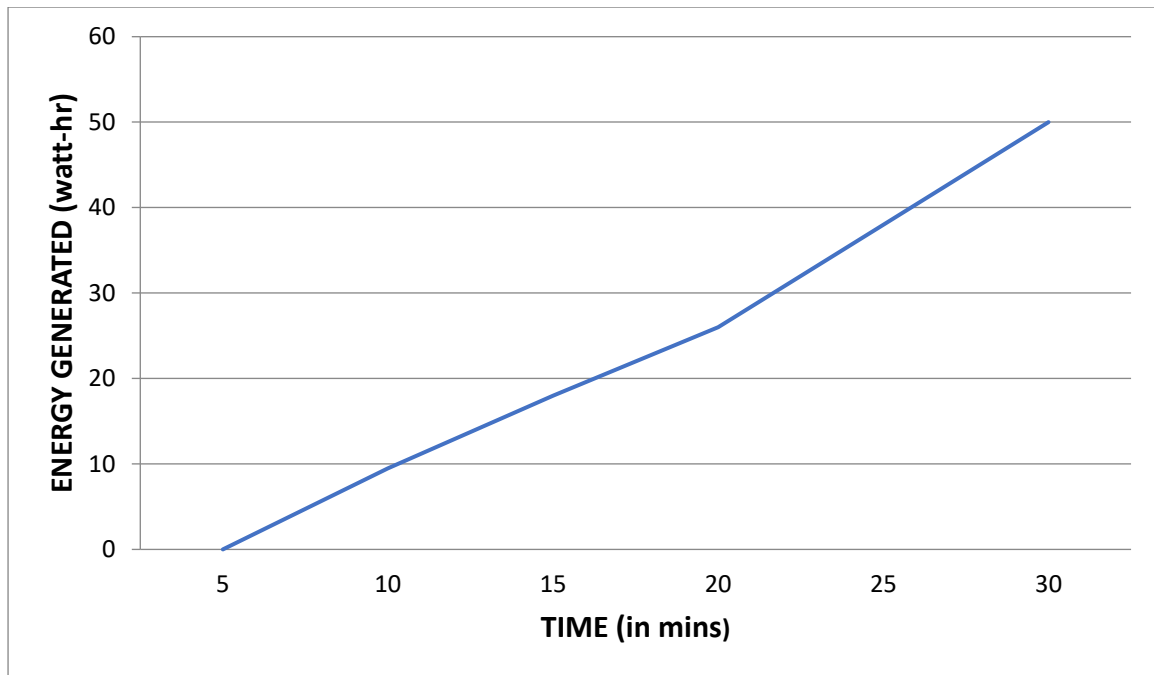


Fig 5.2: Energy vs Time

c. Combined energy/ Hybrid energy Calculations: The combined energy required for charging the battery was calculated based on the individual energy outputs of the piezoelectric sensors and solar panels. Voltage and current readings from both sources were used to determine the total energy needed to charge the battery effectively. This comprehensive approach accounted for energy variability over time intervals, resulting in a range of values from 2.375 to 14.25 watt-hours.

Piezoelectric sensor power = 1.5 watts

Mini solar panel power = 27 watts

Let's calculate the power and energy produced for each time interval:

$$P = V^2 / R$$

Let's plug in the values:

For Voltage = 4.24 V and Resistance = 12 ohms: Power (P) = $(4.24)^2 / 12 \approx 1.5$ watts

For Voltage 18 V and Resistance 12 ohms: Power (P) = $(18)^2 / 12 \approx 27$ watts

So, the power generated for the first scenario is approximately 1.5 watts, and for the second scenario, it's approximately 27 watts.

To calculate the current (I), you can use Ohm's Law, which states that current (I) equals voltage (V) divided by resistance (R)

$$I = V / R$$

Substituting the given values:

$$I = 18.24 / 12$$

$$I \approx 1.52 \text{ amps}$$

So, the current is approximately 1.52 amps

.For 5 minutes:

Piezoelectric sensor energy = 1.5 watts * (5 minutes / 60 minutes per hour) = 0.125 watt-hours

Solar panel energy = 27 watts * (5 minutes / 60 minutes per hour) = 2.25 watt-hours

Combined energy = 0.125 + 2.25 = 2.375 watt-hours

For 10 minutes:

Piezoelectric sensor energy = 1.5 watts * (10 minutes / 60 minutes per hour) = 0.25 watt-hours

Solar panel energy = 27 watts * (10 minutes / 60 minutes per hour) = 4.5 watt-hours

Combined energy = 0.25 + 4.5 = 4.75 watt-hours

For 15 minutes:

Piezoelectric sensor energy = 1.5 watts * (15 minutes / 60 minutes per hour) = 0.375 watt-hours

Solar panel energy = 27 watts * (15 minutes / 60 minutes per hour) = 6.75 watt-hours

Combined energy = 0.375 + 6.75 = 7.125 watt-hours

For 20 minutes:

Piezoelectric sensor energy = 1.5 watts * (20 minutes / 60 minutes per hour) = 0.5 watt-hours

Solar panel energy = 27 watts * (20 minutes / 60 minutes per hour) = 9 watt-hours

Combined energy = 0.5 + 9 = 9.5 watt-hours

For 25 minutes:

Piezoelectric sensor energy = 1.5 watts * (25 minutes / 60 minutes per hour) = 0.625 watt-hours

Solar panel energy = 27 watts * (25 minutes / 60 minutes per hour) = 11.25 watt-hours

Combined energy = 0.625 + 11.25 = 11.875 watt-hours

For 30 minutes:

Piezoelectric sensor energy = 1.5 watts * (30 minutes / 60 minutes per hour) = 0.75 watt-hours

Solar panel energy = 27 watts * (30 minutes / 60 minutes per hour) = 13.5 watt-hours

Combined energy = 0.75 + 13.5 = 14.25 watt-hours

So, the combined energy produced over the specified time intervals by both the piezoelectric sensor and the mini solar panel would be as follows:

Table 5.3: Energy required to charge the battery

TIME (in minutes)	ENERGY GENERATED (in Watts/hr)
5	2.375
10	4.75
15	7.125
20	9.5
25	11.875
30	14.25

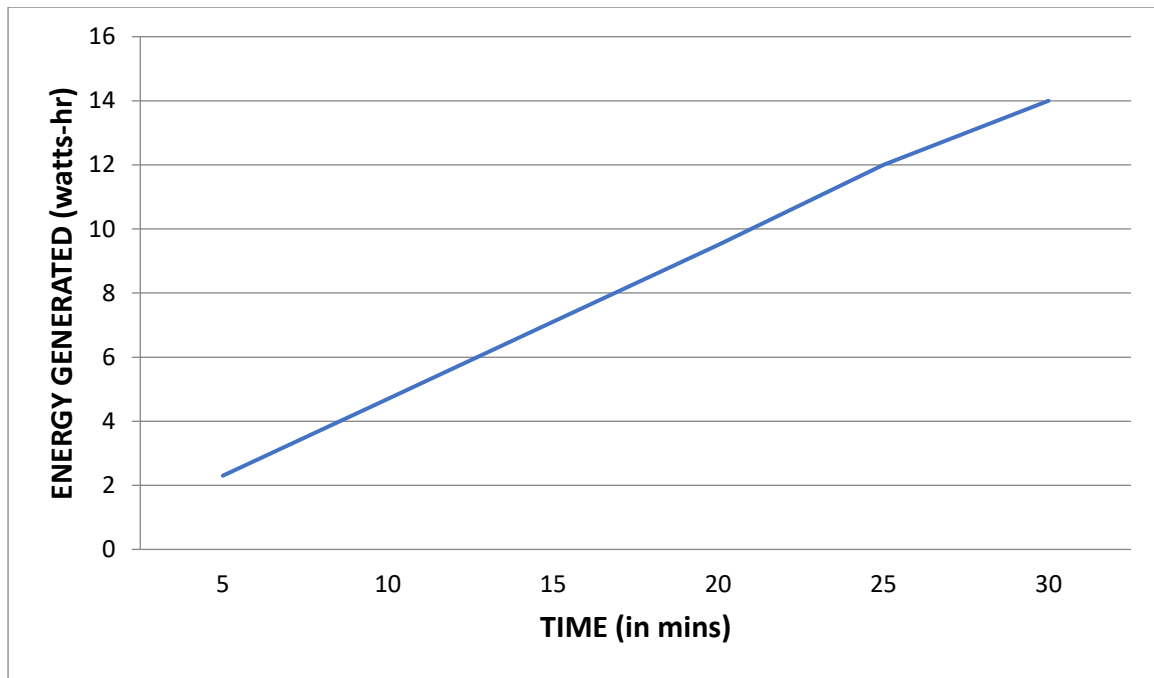


Fig 5.3: Combined Energy vs Time

d. The energy assumption required to charge the battery: Firstly, the combined energy from both the solar panels and piezoelectric sensors was determined to be 20 watts, utilizing a power meter connected to each energy source. Next, the battery capacity, specified at 60 watt-hours, served as a benchmark for determining the energy needed to fully charge the battery. Considering an energy loss of 30% during the charging process, this factor was incorporated into the calculations. The energy loss was determined through voltage and current measurements during charging trials. To calculate the final energy assumption, the combined energy from the solar panels and piezoelectric sensors was adjusted based on the energy loss percentage. This adjusted value represented the effective energy available for charging the battery.

Table 5.4: Energy required to charge the battery

PARAMETER	VALUE
Combined energy from solar panel and piezoelectric sensors	~20 watts
Battery capacity	60 watt-hours
Energy Loss during charging process	30%

Calculations:

Combined energy from piezoelectric and solar panel: 20 watts

Battery capacity: 60 watt-hours

Energy loss during charging process: 30%

First, let's calculate the total energy required to charge the battery:

Total energy required = Battery capacity / (1 - Energy loss)

= 60 watt-hours / (1 - 0.30)

= 60 watt-hours / 0.70

= 85.7 watt-hours

Now, we need to determine the time required to charge the battery with the given combined energy:

Charging time = Total energy required / Combined energy

= 85.7 watt-hours / 20watts

= 4.28 hours

Finally, to find the total energy consumed during charging, we multiply the combined energy by the charging time:

Total energy consumed = Combined energy × Charging time

= 20watts × 4.28 hours

= 85.7watt-hours

So, the total energy consumed to charge the lithium battery using the hybrid energy source would be 85.7 watt-hours. Overall, the estimated results highlight the potential of the integrated energy harvesting system to provide a sustainable and renewable energy solution. By leveraging both solar and rain energy sources, the system offers resilience against weather variability and contributes to reducing dependence on traditional energy sources. Further experimentation and validation in real-world conditions will be crucial to refining the system's performance and maximizing its impact in practical applications.

CHAPTER 6

SUMMARY & CONCLUSION

6.1 SUMMARY:

The smart integrated energy harvesting system project aims to create a sustainable and renewable energy solution by combining solar and rain energy harvesting technologies. Solar panels capture sunlight to generate electricity, providing a consistent power source during daylight hours. Meanwhile, piezoelectric sensors convert raindrop kinetic energy into electrical power, supplementing energy production during rainy periods. A rain sensor accurately detects rainfall intensity, optimizing energy harvesting operations based on weather conditions.

The project utilizes a breadboard for circuit prototyping and integration, ensuring stable and reliable performance. Energy storage and utilization are facilitated by a battery holder and lithium-ion battery, enhancing the system's autonomy and versatility. An LED bulb serves as a demonstration of energy utilization, showcasing the system's capability to power practical applications.

Overall, the project demonstrates the feasibility and potential of integrating multiple renewable energy sources to create a resilient and sustainable energy generation system. By leveraging both solar and rain energy, the system reduces reliance on traditional energy sources and contributes to mitigating environmental impacts. Further experimentation and validation in real-world conditions are essential to refine the system's performance and maximize its effectiveness in practical applications.

6.2 CONCLUSION:

In summary, the evaluation of the integrated energy harvesting system underscores its efficiency and potential impact in renewable energy solutions. Piezoelectric sensors demonstrated a diverse energy generation capacity, ranging from negligible levels to a noteworthy 8 watt-hours over designated time intervals. Similarly, the solar panels showcased a wide spectrum of energy production, spanning from negligible amounts to a substantial 52 watt-hours. Moreover, the calculated

combined energy required for charging the battery showed a range from 2.375 to 14.25 watt-hours, highlighting the system's ability to store and utilize harvested energy effectively. These results underscore the versatility of the system in harnessing both solar and rain energy sources, contributing to sustainable energy solutions. By combining solar panels with piezoelectric sensors, the system ensures continuous energy production regardless of weather conditions, addressing intermittency concerns. Integrated components such as the breadboard and lithium-ion battery enhance adaptability and scalability. Accurate environmental sensing with the rain sensor enables dynamic energy harvesting strategies. The system's ability to power an LED bulb validates its practical applicability. Overall, this project offers a promising solution to global energy challenges, paving the way for a more sustainable future.

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