

IoT Based Solar and Piezoelectric Energy Generation System

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Abstract: This project presents a Hybrid Energy Harvesting System that generates electrical energy using both a solar panel and piezoelectric discs for continuous power generation under different weather conditions. The 12V solar panel harvests solar energy during sunny conditions, while piezoelectric discs convert raindrop impact into electrical energy during rainfall. The AC output from the piezoelectric discs is converted into DC using bridge rectifiers and combined with the solar output to charge a 3-cell lithium-ion battery through a buck converter. An ESP32 microcontroller monitors the battery voltage using a voltage sensor and uploads real-time data to the ThingSpeak cloud platform for remote monitoring and analysis. The system also includes a secondary buck converter to power the ESP32 and a 12V LED bulb as a load. This project provides a low-cost, eco-friendly, and IoT-based solution for efficient renewable energy harvesting and smart energy monitoring.

I. INTRODUCTION

The increasing demand for renewable and sustainable energy sources has encouraged the development of systems that can generate power from natural resources. Solar energy is one of the most widely used renewable energy sources, but its performance decreases during cloudy and rainy conditions. To overcome this limitation, hybrid energy harvesting systems are developed by combining multiple renewable energy sources. In this project, a hybrid energy harvesting system using a solar panel and piezoelectric discs is designed to generate electricity from both sunlight and raindrop impact.

The solar panel converts solar energy into electrical energy during daytime, while the piezoelectric discs produce electrical energy when raindrops strike their surface. The generated energy is stored in a lithium-ion battery through a regulated charging circuit. An ESP32 microcontroller is used to monitor the battery voltage and upload real-time data to the ThingSpeak cloud platform for remote monitoring. This system ensures better energy availability in different weather conditions and provides a low-cost, eco-friendly, and IoT-enabled solution for renewable energy generation and smart monitoring applications.

II. RELATED WORK

1. T. Markvart and L. Castañer (2019)

T. Markvart and L. Castañer published research on photovoltaic solar energy systems and their applications in renewable energy generation. Their work explained the working principle of solar panels, energy conversion efficiency, and battery charging techniques for off-grid systems. The study also highlighted the limitations of solar power generation during cloudy and rainy weather, which motivated the development of hybrid renewable energy systems.

2. S. Priya and D. J. Inman (2016)

S. Priya and D. J. Inman conducted research on piezoelectric energy harvesting methods using vibrations and raindrop impacts. Their study demonstrated that piezoelectric materials can convert mechanical stress into electrical energy and can be used in low-power applications. The authors concluded that connecting multiple piezoelectric discs improves the overall energy output and efficiency of rain energy harvesting systems.

3. M. A. M. Ramli and H. R. E. H. Boucekara (2018)

M. A. M. Ramli and H. R. E. H. Boucekara proposed a hybrid renewable energy system combining solar and piezoelectric energy sources. Their research focused on improving energy availability under different environmental conditions. The system was capable of generating electricity during both sunny and rainy weather, thereby increasing system reliability and reducing dependence on a single energy source.

4. A. Al-Fuqaha, M. Guizani, and M. Mohammadi (2015)

A. Al-Fuqaha and co-authors studied IoT-based smart monitoring systems using wireless communication technologies. Their work explained the use of microcontrollers and cloud platforms for collecting, transmitting, and analyzing sensor data remotely. The study showed that IoT technology improves monitoring efficiency and enables real-time supervision of renewable energy systems.

5. B. Scrosati and J. Garche (2010)

B. Scrosati and J. Garche researched lithium-ion battery technologies and charging methods for renewable energy applications. Their study explained the importance of battery management systems (BMS) and voltage regulation circuits in protecting batteries from overcharging, over-discharging, and short circuits. The research improved battery safety and operational efficiency in energy storage systems.

6. MathWorks Research Team (2017)

The MathWorks Research Team developed the ThingSpeak cloud platform for IoT-based real-time monitoring applications. Their work demonstrated how sensor data can be uploaded, visualized, and analyzed remotely using cloud services. The study proved that ThingSpeak is an effective platform for monitoring renewable energy systems, battery status, and environmental conditions through graphical dashboards and alerts.

III. PROPOSED WORK**A). METHODOLOGY**

The proposed system is a hybrid energy harvesting and monitoring setup that combines piezoelectric energy and solar energy for charging a battery and powering a load. The complete working methodology of the project is explained below.

1. Energy Generation Using Piezoelectric Discs

- Multiple piezoelectric discs are placed in locations where mechanical pressure or vibrations occur.
- When force is applied on the piezo discs, they generate AC voltage due to the piezoelectric effect.
- Each piezo disc is connected to an individual bridge rectifier to convert the generated AC voltage into DC voltage.

2. DC Rectification and Energy Storage

- The DC outputs from all bridge rectifiers are connected together.
- A capacitor is used after the rectifier stage to smooth the fluctuating DC voltage and temporarily store the harvested energy.
- This improves voltage stability before supplying power to the charging circuit.

3. Solar Panel Integration

- A 12V solar panel is integrated as an additional renewable energy source.
- The solar panel output and capacitor output are connected to the input of the buck converter charge controller.
- This hybrid arrangement increases charging efficiency and ensures power availability even when piezo generation is low.

4. Battery Charging Section

- A buck converter charge controller regulates the incoming voltage from the solar panel and piezoelectric section.
- The regulated output is used to charge a 3S Li-ion battery pack rated at 11.1V.
- The charge controller prevents overcharging and maintains safe battery charging conditions.

5. Power Supply to the System

- The charged battery acts as the main energy storage unit.
- The battery output is distributed to different sections of the project:

1. Load section

2. Monitoring section

3.ESP32 controller section

6. Voltage Regulation for ESP32

- Since ESP32 operates at 5V, a second buck converter is used to step down the battery voltage from 11.1V to 5V.
- This regulated supply powers the ESP32 microcontroller safely.

7. Battery Voltage Monitoring

- A voltage divider sensor is connected across the battery terminals.
- The sensor reduces the battery voltage to a safe measurable range for the ESP32 analog input.
- ESP32 continuously monitors the battery voltage level.

8. IoT-Based Data Monitoring

- The ESP32 processes the voltage data and sends it to the ThingSpeak cloud platform using Wi-Fi.
- Real-time monitoring of battery voltage and system performance can be viewed remotely through the cloud dashboard.

9. Load Operation

- A switch is connected between the battery and the 12V LED bulb.
- When the switch is turned ON, the battery powers the LED load.
- The stored hybrid energy is therefore utilized for practical lighting applications.

10. Overall System Operation

- Mechanical pressure on piezo discs and sunlight on the solar panel generate electrical energy.
- The generated energy is rectified, filtered using a capacitor, and regulated through the buck converter.
- Energy is stored in the Li-ion battery and later used for powering the LED bulb and IoT monitoring system.
- The system demonstrates efficient renewable energy harvesting, storage, and smart monitoring in a compact setup.

B). Working Principle

The proposed system operates on the principle of hybrid renewable energy harvesting by combining piezoelectric energy and solar energy for efficient power generation and storage. When mechanical pressure or vibrations are applied to the piezoelectric discs, they generate AC electrical signals through the piezoelectric effect. These AC signals are converted into DC using bridge rectifiers, and the output is stabilized using a capacitor that acts as a filtering and temporary energy storage element. Simultaneously, a 12V solar panel generates DC power using the photovoltaic effect. The combined output from the piezoelectric section and solar panel is supplied to a buck converter charge controller for regulated charging of the 3S Li-ion battery pack.

The stored energy in the Li-ion battery is used to power the entire system, including the ESP32 controller and the 12V LED load. A voltage divider sensor continuously monitors the battery voltage and sends the scaled signal to the ESP32 microcontroller. The ESP32 processes the data and uploads it to the ThingSpeak cloud platform through Wi-Fi for real-time monitoring and analysis. Thus, the system enables continuous energy harvesting, regulated energy storage, IoT-based monitoring, and efficient utilization of renewable energy for practical applications.

C). System design approach:

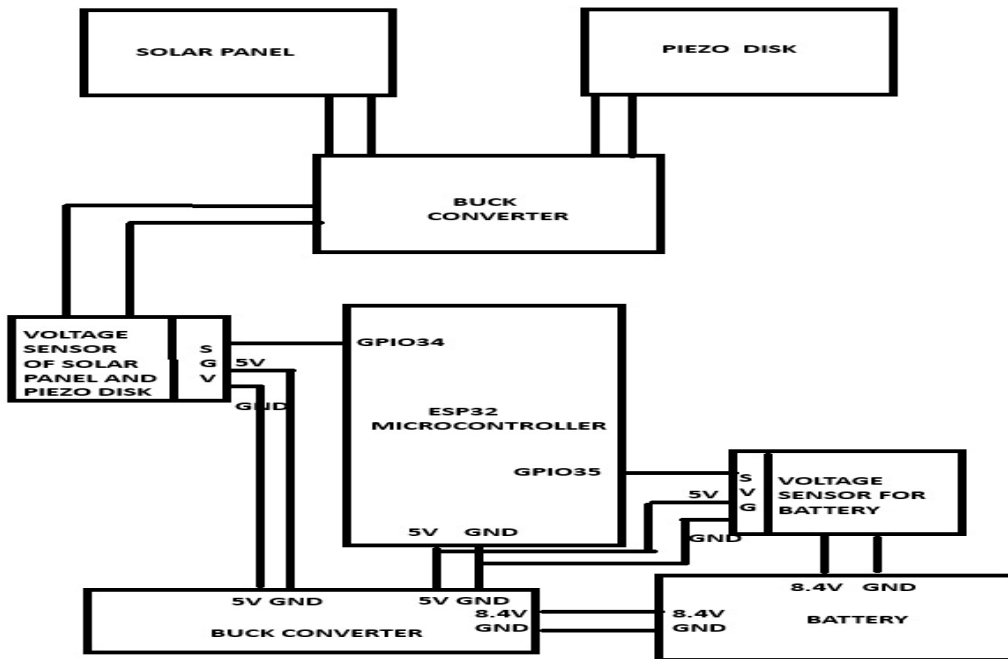


Fig.1. Block diagram

Fig. 1 This system represents a hybrid energy harvesting and monitoring circuit using a solar panel and piezo disk as the input power sources. The solar panel converts sunlight into electrical energy, while the piezo disk generates electrical energy from mechanical vibrations or pressure. Both sources are connected to a buck converter, which regulates and steps down the fluctuating input voltage into a stable output voltage suitable for charging the battery and powering the ESP32 microcontroller. A voltage sensor is connected to the solar panel and piezo disk output to continuously monitor the generated voltage levels. The sensor sends the measured analog voltage data to the ESP32 through GPIO34 for real-time monitoring and analysis.

The battery acts as the energy storage unit and supplies power to the overall system. Another voltage sensor is connected across the battery terminals to measure the battery voltage and provide feedback to the ESP32 through GPIO35. The second buck converter regulates the battery voltage to a stable 5V supply required for operating the ESP32 and sensors safely. The ESP32 microcontroller serves as the central processing unit of the system, collecting voltage data from both sensors, monitoring power generation and battery status, and enabling efficient energy management. This setup is mainly used in renewable energy applications where multiple energy sources are combined to achieve reliable and continuous power generation.

D). Proposed Workflow:

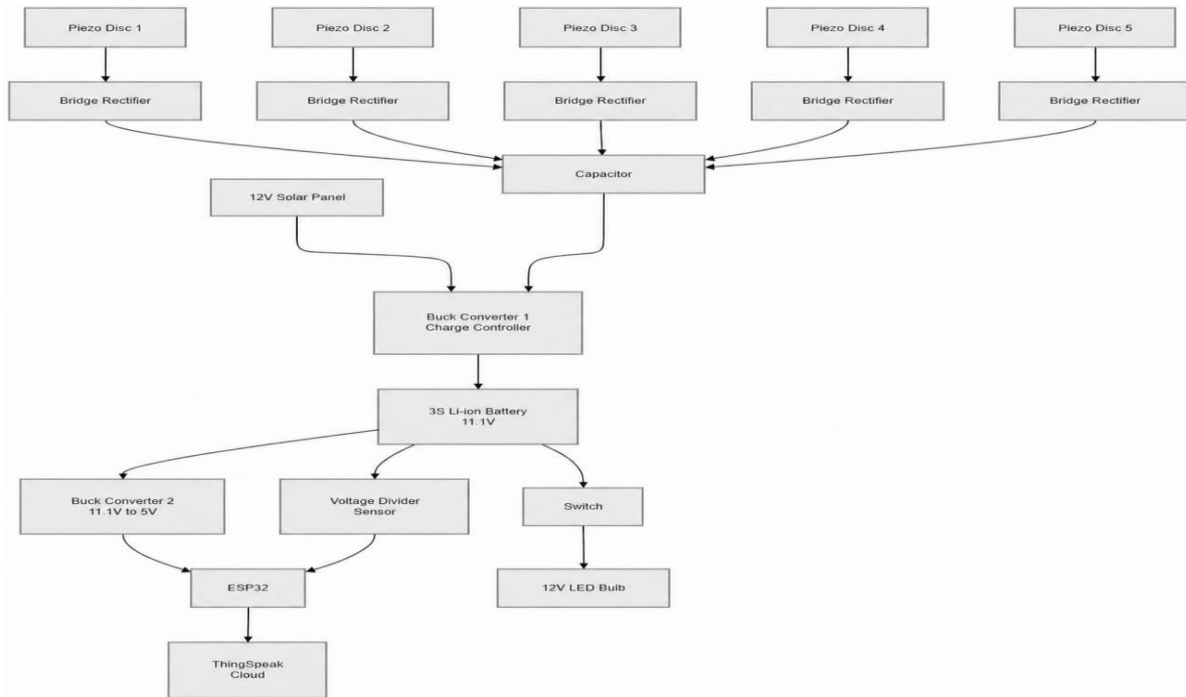


Fig 2. Flow Chart

Fig. 2 The flowchart represents a hybrid energy harvesting and smart monitoring system that combines energy from piezoelectric discs and a solar panel to charge a battery and power a load. Initially, five piezo discs are used to generate electrical energy from mechanical vibrations or pressure. Since the output from piezoelectric sensors is AC in nature, each piezo disc is connected to a bridge rectifier which converts the AC voltage into DC voltage. The rectified outputs from all piezo discs are then combined and stored temporarily in a capacitor. The capacitor acts as an energy storage and filtering component, smoothing the fluctuating voltage generated by the piezo discs. Along with this, a 12V solar panel also supplies DC power, and both energy sources are connected to Buck Converter 1 (charge controller) to regulate the charging process safely.

The regulated output from the charge controller is used to charge a 3S Li-ion battery rated at 11.1V. The battery serves as the main energy storage unit of the system. From the battery, power is distributed to different sections of the circuit. One path is connected to a switch and a 12V LED bulb, which acts as the output load. Another path is connected to Buck Converter 2, which steps down the battery voltage from 11.1V to 5V to power the ESP32 microcontroller. A voltage divider sensor continuously monitors the battery voltage and sends the measured data to the ESP32. The ESP32 processes this information and uploads the battery and system status to the ThingSpeak cloud platform for real-time IoT monitoring and analysis. This system enables efficient renewable energy harvesting, storage, load operation, and remote monitoring in a single integrated setup.

IV. RESULTS

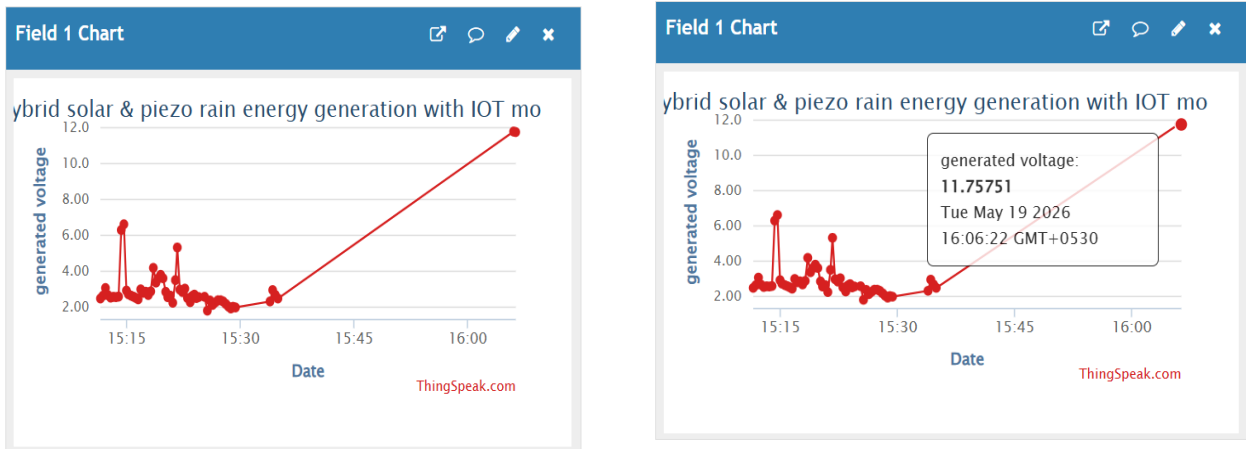


Fig.5.1

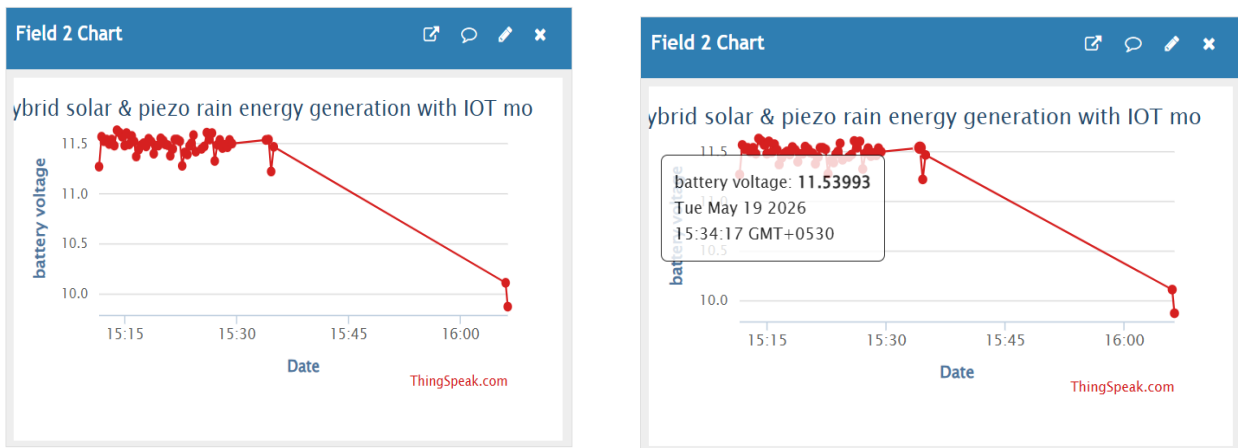


Fig.5.2

IoT Based Solar and Piezoelectric Energy Generation System using Thingspeak

Fig. 5.1 Generated Voltage Monitoring using ThingSpeak

Fig. 5.1 shows the real-time generated voltage obtained from the hybrid solar and piezoelectric energy harvesting system using the ThingSpeak IoT platform.

- * Field 1 Chart represents the generated voltage produced by the hybrid renewable energy system.
- * The generated voltage varies continuously depending on solar intensity and piezoelectric vibration conditions.
- * Initially, the generated voltage fluctuates between approximately 2 V and 6.5 V.
- * The maximum generated voltage observed in the system is approximately 11.75 V.
- * The generated data is uploaded to the ThingSpeak cloud platform along with date and time information.
- * The obtained results confirm that the hybrid energy harvesting system successfully generates electrical energy under varying environmental conditions.
- * The IoT monitoring system enables real-time remote observation of generated power through the internet.

Fig. 5.2 Battery Voltage Monitoring using ThingSpeak

Fig. 5.2 shows the battery voltage monitoring characteristics of the proposed IoT-based energy harvesting system.

- * Field 2 Chart represents the battery voltage monitored through the IoT platform.
- * The battery voltage remains nearly stable around 11.5 V during charging operation.
- * The monitored battery voltage recorded is approximately 11.53 V during normal operation.
- * At later intervals, the battery voltage gradually decreases due to load consumption and battery discharge.
- * The monitored data is continuously transmitted to the ThingSpeak IoT cloud platform with real-time date and time updates.
- * The obtained results demonstrate successful battery charging and energy storage operation in the proposed hybrid system.
- * The IoT-based monitoring system helps in remote supervision of battery condition and renewable energy generation performance.

VI. CONCLUSION & FUTURE SCOPE**Conclusion:**

The proposed hybrid energy harvesting system successfully integrates piezoelectric energy generation and solar energy harvesting into a single efficient platform. The system collects mechanical vibration energy through piezo discs and combines it with solar power to charge an 11.1V Li-ion battery using a regulated buck converter charge controller. The stored energy is effectively utilized to power a 12V LED load while simultaneously supporting IoT-based monitoring through the ESP32 microcontroller and ThingSpeak cloud platform. The inclusion of voltage monitoring and wireless data transmission improves system reliability and enables real-time performance analysis. Overall, the project demonstrates an eco-friendly, cost-effective, and sustainable approach for renewable energy harvesting and smart energy management applications

Future Scope:

The future scope of this project can be extended by increasing the number of piezoelectric sensors and integrating higher-capacity solar panels to improve overall energy generation efficiency. Advanced power management techniques such as MPPT (Maximum Power Point Tracking) can also be implemented for optimized charging performance. The system can further be upgraded by adding multiple sensors to monitor current, temperature, and power consumption in real time. Machine learning algorithms and predictive analytics can be integrated with cloud platforms for intelligent energy management and fault detection. In future, this technology can be applied in smart roads, railway tracks, industrial machinery, wearable devices, and smart city applications where waste mechanical energy can be converted into useful electrical energy for sustainable development.

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