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Solar-Piezo Energy Harvesting System for Battery Charging

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Abstract: This research project looks into the design and implementation of a Solar-Piezo Energy Harvesting System for Battery Charging, with the goal of reducing reliance on traditional energy networks while promoting sustainability. By combining solar and piezoelectric energy sources, the system efficiently charges batteries, meeting users' diverse energy needs. Real-time monitoring using an LCD display provides instant feedback on energy availability and charging status, improving user experience and allowing for informed decisions about energy usage optimization. This initiative represents a significant step forward in sustainable energy practices, addressing the growing demand for efficient battery charging solutions in a variety of applications. The system's dependability is enhanced by efficient battery charging, which ensures consistent voltage regulation and smooth transitions between solar and piezoelectric sources for continuous power supply.

Keywords— Arduino uno, IoT, piezo energy, solar energy, battery charging, renewable energy.

Introduction

In recent years, the increasing demand for sustainable energy solutions has led to significant advancements in renewable-energy technologies. Among these technologies, solar and piezoelectric energy harvesting have emerged as promising sources of clean and renewable power. Solar photovoltaic systems have become widely adopted for generating electricity from sunlight, while piezoelectric materials can convert mechanical strain into electrical energy. By leveraging the complementary nature of these two sources, our research focuses on the development and implementation of a solar–piezoelectric energy-harvesting system for battery charging. The motivation behind this research is the pressing need to reduce our dependence on conventional energy networks and mitigate the environmental impact of energy generation. Conventional fossil-fuel-based power generation not only contributes to greenhouse gas emissions but also poses risks to global energy security. By harnessing solar and piezoelectric energy, we aim to provide an alternative sustainable solution for battery charging that promotes energy independence and environmental stewardship.

The integration of solar and piezoelectric energy sources into our system brings numerous advantages. By capturing sunlight during the day and ambient vibrations or mechanical strains in the surrounding area, our hybrid approach guarantees a more dependable and robust energy supply compared to relying solely on one source. Furthermore, the versatility of the system, which allows it to charge batteries of various types and sizes, makes it suitable for a wide range of applications, from portable electronics to electric vehicles. Moreover, real-time monitoring and feedback mechanisms enhance the user experience and improve energy usage efficiency. By providing users with instant information on energy availability, charging status, and overall system performance, we empower them to make well-informed decisions and optimize energy usage. This not only increases the efficiency of the charging process but also extends the lifespan of batteries and reduces energy waste.

The purpose of this research paper is to introduce a solar-piezoelectric energy harvesting system for battery charging. The paper delves into the fundamental concepts of solar and piezoelectric energy harvesting, and their integration into a unified system. The performance characteristics of the system in real-world scenarios are also explored. Furthermore, the research highlights the potential implications on sustainable energy practices and the applications of the developed system. The ultimate goal is to advance renewable energy technologies and promote sustainable energy solutions for a greener future.

Literature review

This section provides a summary of earlier research on the compression testing device to harvest electric energy K.Varalaxmi Nithya [1], This paper focuses on tackling the global energy crisis by harnessing a non-conventional energy source: human locomotion energy. To address the pressing issue of energy scarcity, the paper proposes a practical solution that involves capturing and converting the energy generated by people's footsteps into electric power. This is achieved through the use of piezoelectric sensors strategically positioned to detect the vibrations and pressure generated when individuals walk. The energy generated by the sensors is harvested and subsequently used for a specific application—charging mobile devices. This innovative approach not only offers a practical means of energy generation but also encourages a more sustainable and eco-friendly way of meeting power demands, particularly in areas with significant pedestrian traffic.

Kunal Soni [2] focuses on tapping into an often-underutilized energy source, produced by human locomotion, which includes activities like skipping and running. It focused on capturing and storing this human-generated energy. The authors employ piezoelectric sensors strategically placed beneath a platform to maximize the voltage generated by footstep pressure. This harnessed energy is subsequently stored in batteries, ensuring its availability when needed. This is significant for the pedestrian population, emphasizing its practicality in regions where human locomotion is a common mode of transportation. Another research done by Kunal Padam [3] the paper suggests that low-powered electronic devices are being used more frequently. The most common activity for humans is walking. A person's footsteps release energy onto the surface when they walk. This energy is captured and transformed into electrical energy, such as that used to charge a phone every step. When the body applies external pressure to a shoe equipped with piezoelectric sensors, the pressure is converted into electrical energy. The material that generates electricity when pressure from the outside is applied is known as a piezoelectric sensor.

Sdeel Ali [4]. The study describes how the piezoelectric phenomenon causes materials to produce an electric charge when pressure from the outside is applied. When stress or pressure is applied to materials containing piezoelectric sensors, they exhibit reversal behavior, which means that the materials produce pressure in the form of electric energy. Although this material can be used in a variety of modes that are sufficiently responsive to external forces, bending has the maximum sensitivity.The paper by Se Yeong Jeong [5] examines a wireless communication system that uses piezoelectric materials to generate electricity on its own. It is positioned beneath the shoe's sole and has a straightforward construction. The pushing tester was used to test the project, and it was also analyzed that the operation of a step-down converter generates enough energy to run a wireless transmitter. After 24 steps, the transmitter can be used for the first time. When the transmitter sends out a signal, the control center may monitor worker status and identify any emergencies.

M Logeshwaran [6] used piezoelectric materials to capture mechanical energy and use it to generate electricity. A piezoelectric generator, which produces electricity by converting pressure and vibrations, is shown in this paper. It focuses on integrating piezoelectric sensors under flooring to harvest energy from foot traffic. Lithium-based batteries are used to store the gathered energy, which is then enhanced by a DC booster module. This system's potential usefulness is demonstrated by its actual use in crowded locations.

T Sarala [7] addresses the pressing need for electricity while considering environmental concerns, this paper focuses on harnessing human energy using non-conventional methods. It introduces the use of piezoelectric tiles to capture waste energy generated from walking. The generated electricity is stored in lead-acid batteries and employed to automate street lighting with Light Dependent Resistor (LDR) sensors. Furthermore, the system's status is displayed on a Liquid Crystal Display (LCD), demonstrating a sustainable and practical solution for energy generation and utilization.Sajal Sahu [8] this paper explores the concept of power generation through footsteps, capitalizing on the piezoelectric effect in materials. Given the escalating global demand for energy, the focus on utilizing the abundant energy potential in human footsteps aligns with the needs of densely populated nations, such as China and India. For developing economies grappling with energy shortages, the proposal to harness foot power waste energy holds relevance. The study elucidates the application of piezoelectric materials to capture and store energy from various sources of vibrations, particularly human foot traffic. The operational principle centers on piezoelectric sensors integrated into flooring, where they convert pressure-induced energy into electrical charges. These sensors find practical deployment in high-traffic areas like footpaths, malls, and complexes, where significant mechanical energy goes to waste, offering a sustainable solution to energy needs.

Hu Shi [9] paper delves into the allocation of energy sources stemming from daily human activities, dissecting the available human energy in alignment with generation principles. It expands upon the idea of harnessing human walking energy and extends it to wearable walking robotics, employing alternative mediums like fluids for power transmission in lieu of electricity. The study employed dielectric elastomer-powered boot generators to generate electricity through human motion, with a particular emphasis on the concept of energy harvesting.K. Sai Bhargav [10] this research primarily centers on the generation of electrical power through the kinetic energy produced by people walking and the pressure exerted during each step. It delves into the process of converting mechanical power into electrical energy through the use of transducers. While this approach may not fully satisfy the global demand for electricity, it offers a means to convert and diminish reliance on conventional methods of electricity generation.

Methodology / experimentation

Integration of piezoelectric technology with solar energy is a new sustainable and efficient way to harvest energy from both light and mechanical energy.

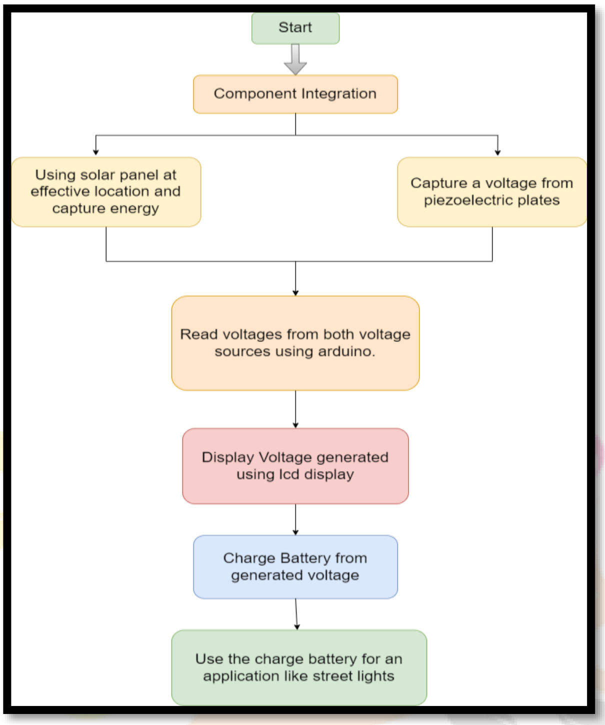

Fig1. Flowchart

Component Integration:

Table 1 Component Specifications Table

Components	Description
Arduino Uno	A small microcontroller board that includes 14 digital I/O pins (6 PWM), 6 analog inputs, and USB connectivity, featuring ATMega328p microcontroller
Solar panel	A Max 6-volt solar panel typically contains photovoltaic cells that convert sunlight into electricity, providing a portable and environmentally friendly power solution for a variety of applications.
piezoelectric plates	Piezo plates are thin, flat devices made of piezoelectric materials that produce an electric charge when mechanical stress is applied. electronics to automotive.
TP4056	The TP4056 is a single-cell lithium-ion battery charging integrated circuit that includes adjustable charging current, constant-current/constant-voltage charging stages, and overcharge and short-circuit protection.
Battery	3.7 volt lithium-ion battery for storing the harvested electricity from solar and piezoelectric material.
LCD display	LCD displays for Arduino are small visual output devices used in electronic projects to display data and information. They provide users with a variety of real-time feedback, sensor readings, and menu options.
Jumper wires	Jumper wires are flexible and there is no need for soldering. Easy to connect with each other
Breadboard	It’s a construction base.

1. Energy Harvesting:
    a. Solar panels capture sunlight using photovoltaic cells made of semiconductor materials such as silicon. When sunlight strikes these cells, electrons are knocked loose from their atoms, resulting in an electrical current. These electrons are collected by metal conductive plates and transferred to wires as electricity. This direct current (DC) electricity is then converted by an inverter into alternating current (AC) electricity that can be used in homes and businesses. This generated voltage is also read using arduino further use for charging the battery.

Fig.2 Solar plate

    b. Piezoelectric materials are capable of converting mechanical energy to electrical energy. When piezoelectric plates are placed on the ground or roads and subjected to pressure from passing vehicles or pedestrians, they produce voltage. This voltage can be harnessed and used for a variety of purposes, here used for charging batteries. To measure the voltage produced by the weight on the piezo plates, an Arduino board is used. The Arduino board reads the voltage output from the piezo plates.

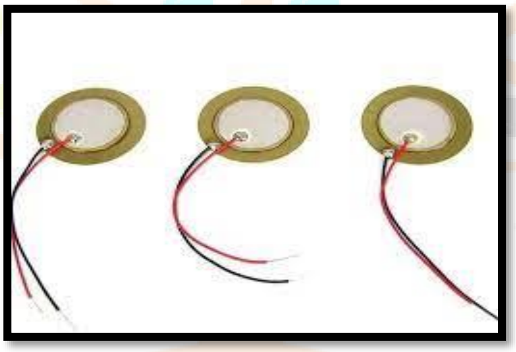

Fig. 3 Piezoelectric plates

2. After connecting the solar panel and piezo plate circuits to the Arduino board it reads the voltage from both energy sources on the different pins. Now using the LCD Display displays the voltage individually for a specific time interval. From this, we keep on track of the voltage generation. Also using diodes makes a rectifier circuit for rectifying the current for battery charging.

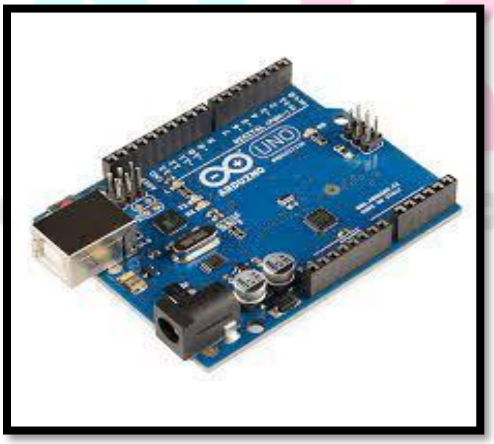

Fig. 4 Arduino Uno board

3. To store the generated electricity here used the TP4056 is a linear lithium-ion battery charger integrated circuit that is commonly used in portable electronic devices. It uses a constant-current/constant-voltage charging method, first providing a steady current to the battery until it reaches a preset voltage threshold, then switching to a constant voltage

mode. This mode allows the current to gradually reduce until the battery reaches full charge. The TP4056 also includes features like automatic recharge, over-temperature protection, and under-voltage lockout to ensure the safe and efficient charging of lithium-ion batteries.

Fig.5 TP4056

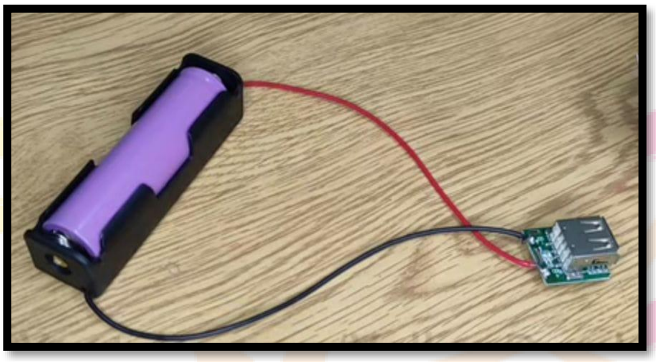

Fig.6 Power Module

Calculations

1. Assume that average sunlight in a day = 5-6 hours
   Daily solar energy = solar panel wattage × Hours
   = 6 × 5
   = 30 Wh(watt-hours)
2. Average car weight: Around 1500 kg (1.5 metric tons) .
   Each car exerts a force of approximately 5000 Newtons on the road surface (assuming uniform pressure distribution and simplified calculations). Piezoelectric efficiency: 20%.
   Assuming that 100 cars per minute passing over a one-kilometer stretch of road

   Total Force Exerted by Cars per Hour:
   Force= Cars per minute × 60 Force
   = Cars per minute×60 Force
   = 100 cars/minute × 60
   = 6000 cars/hour Force
   = 100cars/minute×60
   = 6000 cars/hour

   Calculation of Force in Newtons per Hour:
   Force = 6000 cars/hour × 5000 Newtons
   =30,000,000 Newtons/hour Force
   =6000 cars/hour×5000 Newtons
   =30,000,000Newtons/hour

   Energy Conversion Considering Efficiency:
   Assumed efficiency of 20%, to calculate the energy converted to electrical energy over the course of an hour, assuming a distance of 1000 meters:

   Energy = Force × Distance × Efficiency
   = 30, 000,000 N/hour × 1000 m × 0.2
   =60,000,000,000Joules/hour

Therefore, the energy potential derived from the force exerted by cars passing through the specified distance, considering a 20% efficiency rate, amounts to 60,000,000,000 Joules per hour.

Result And discussion

Result and observation from hybrid power system are as follow:
Here the analysis of voltage, current and power generated from both solar and piezo sources per hour was conducted.

	Solar Energy	Piezoelectric Energy
Average Voltage (V)	6.3375 volts	3.6625 volts
Average Current (A)	0.7 amps	0.0625 volts
Average Power (W)	4.6375watts	0.2185 watts

These tables provide information on the typical performance of both energy producing technologies. While the solar panel produces significantly more power than the piezoelectric device, the latter contributes to total energy generation, although on a smaller scale. This data emphasizes the variety of renewable energy extraction techniques and the significance of optimizing each system's efficiency for long-term energy production.

Conclusion

By decreasing dependency on conventional energy networks, the efficient battery charging system's integration of solar and piezoelectric energy not only satisfies various energy needs of users but also advances sustainability. This combination provides a stable power supply that can charge several kinds of batteries, meeting a range of user needs. Additionally, instantaneous feedback on energy availability, charging status, and overall system performance is provided using the LCD display's real-time monitoring feature, which improves user experience. This real-time information enables users to optimize utilization of resources by making informed decisions about energy usage. All things considered, this initiative is a major step forward for sustainable energy practices and satisfies the growing need for effective battery charging solutions for a wide variety of applications. The system's dependability is further increased by the efficient battery charging, which is defined by steady voltage regulation and management in both solar and piezoelectric charging modes. The seamless transitions between solar and piezoelectric sources guarantee a continuous power supply to the load.

Future scope

In the future, there are several opportunities to improve the combination of solar and piezoelectric power for charging batteries. Future studies could focus on increasing the efficiency and scalability of the system by enhancing the design and materials used in the components. Using machine learning and artificial intelligence techniques may help create predictive models for energy generation and consumption patterns, which would improve the performance and adaptability of the system. Additionally, incorporating other renewable energy sources like wind and hydroelectric power may make the energy system more resilient. It is crucial to address the practical challenges of deployment and investigate cost-reduction strategies to ensure the system is feasible for real-world use. Overall, ongoing research efforts are promising for advancing sustainable energy technologies and creating a cleaner and more resilient energy future.

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