Grenze International Journal of Engineering and Technology, June Issue

Mechanical Energy Harvesting from Footprints for Renewable Energy Applications

Shivappa H.A[1], Preethi K[2], Tejesh S[3], Srinivasu N[4], Manjunath T.C[5] and Shashidhar V[6]
[1-4]Assistant Professor/s, Department of Mechanical Engineering, Dr. Ambedkar Institute of Technology, Bangalore, Karnataka, India
Email: tcmanju@iitbombay.org
[5]Dean Research (R & D), Professor, Computer Science & Engineering, Rajarajeswari College of Engineering, Bangalore, Karnataka
[6]Associate Professor & HoD, Computer Science & Engineering Department (IoT, CS, BCT), Rajarajeswari College of Engineering, Bangalore, Karnataka

***Abstract*— The work undertaken focuses on the design, development, and implementation of a footprint-based energy harvesting system, aimed at harnessing renewable energy from everyday human activities This project focuses on designing and implementing a footprint-based energy harvesting system that converts human footsteps into usable electrical energy using piezoelectric plates. These plates, arranged beneath a robust walking platform, deform slightly under pressure, generating electrical charges. The small amounts of AC voltage produced are converted to DC using a bridge rectifier and stored in rechargeable batteries. Voltage regulators, capacitors, and transformers ensure safe and stable storage. A microcontroller monitors key parameters like voltage, current, and energy generation in real-time. The modular design allows scalability, making it suitable for areas like public walkways and institutions. The harvested energy, though small, is enough to power devices like LEDs, mobile chargers, and clocks. This prototype supports green infrastructure and educates on renewable energy. It promotes the use of micro-energy systems and paves the way for smart city applications, standing as a small yet impactful step toward sustainable, decentralized energy system**

***Index Terms*—Energy, LED, Generation, Power, Harvesting, Regulator.**

I. Introduction

This project focuses on designing and implementing a footprint-based energy harvesting system that converts human footsteps into usable electrical energy using piezoelectric plates. These plates, arranged beneath a robust walking platform, deform slightly under pressure, generating electrical charges. The small amounts of AC voltage produced are converted to DC using a bridge rectifier and stored in rechargeable batteries. Voltage regulators, capacitors, and transformers ensure safe and stable storage. A microcontroller monitors key parameters like voltage, current, and energy generation in real-time. The modular design allows scalability, making it suitable for areas like public walkways and institutions. The harvested energy, though small, is enough to power devices like LEDs, mobile chargers, and clocks. This prototype supports green infrastructure and educates on renewable energy. It promotes the use of micro-energy systems and paves the way for smart city applications, standing as a small yet impactful step toward sustainable, decentralized energy system.

Grenze ID: 01.GIJET.12.2.444_24

This project aims to design and implement a functional prototype of a footprint-powered energy harvesting system using piezoelectric plates. The design ensures durability, safety, and sensitivity to effectively capture energy while withstanding repeated human traffic. The modular architecture allows for easy scalability, so the system can be expanded to larger areas depending on energy requirements [1][2].
In addition to its practical applications, this technology has great potential in raising public awareness about renewable energy and energy conservation. It turns passive infrastructure into active contributors to the energy grid and promotes the idea of smart environments—where buildings and public spaces not only consume energy but also produce it. Moreover, it opens up new avenues for energy generation in remote or off-grid locations where access to traditional electricity sources is limited. The goal of this project is not only to prove the concept but also to demonstrate that sustainable energy can be generated through the kinetic energy we produce unconsciously every day. By successfully implementing this system within a localized environment—such as an educational institute or public building—it becomes a step forward in promoting environmentally responsible innovation and building a foundation for smart, self-sustaining infrastructure in the future [3][4].

II. Objective / Aim of the Project Work

The primary aim of this project is to design, develop, and successfully implement a prototype system that utilizes piezoelectric materials to harvest mechanical energy generated from human footsteps and convert it into usable electrical energy. This system aims to demonstrate a practical and environmentally friendly method of micro-energy generation, highlighting the potential of everyday human activity as a renewable energy source. The project emphasizes the integration of energy conversion, regulation, storage, and monitoring into a compact, modular, and scalable platform that can be installed in highfootfall areas such as educational institutions, public transportation hubs, shopping malls, and commercial buildings. The broader aim is to support the global movement toward sustainable development by exploring alternative sources of green energy and raising public awareness about the feasibility of energy harvesting technologies [5][6].

III. Literature Survey

Piezoelectric materials are extensively researched for their ability to convert mechanical pressure into electrical signals, making them ideal for energy harvesting and smart switching systems. Studies have shown that piezoelectric discs generate small alternating voltages when stressed, which can be rectified and stored. Demonstrated that a full-wave bridge rectifier using diodes like 1N4007 is effective for converting the piezo's AC output into a usable DC signal. This rectified signal, when filtered using a capacitor-resistor combination, produces a smoother voltage suitable for microcontroller input. Arduino boards are often used in such systems due to their flexibility in analog signal reading and digital control Arduino can read voltage from sensors and trigger actions such as lighting a bulb. In this project, the filtered DC voltage is fed into analog pin A0 of the Arduino Uno, which processes the signal and compares it against a threshold. If the voltage exceeds the threshold, the Arduino sends a HIGH signal through pin 8 to drive a BC547 NPN transistor. Literature supports the use of BC547 for switching low-power devices, acting as an interface between Arduino and external loads like bulbs. Additionally, to enhance user interaction, an I2C LCD is used to display the live piezo value and bulb status, connected through pins A4 (SDA) and A5 (SCL). Recent studies also highlight the integration of such piezo-Arduino systems in real-time applications like smart floors, energy-saving walkways, and footstep-powered street lights [7][8]..

IV. Outcome of the Project

- The expected outcomes of footprint power generation using piezoelectric plates include the successful conversion of mechanical energy from foot traffic into usable electrical energy,
- contributing to a sustainable and eco-friendly power source. This technology is anticipated to provide a reliable, low-maintenance solution for powering small-scale applications such
- as LED lights, sensors, and other low-power devices in high-footfall areas. Additionally, it is expected to promote energy awareness and innovation in urban infrastructure by
- integrating energy-harvesting systems into everyday environments like sidewalks, train stations, and commercial buildings. The implementation of such systems may also offer
- valuable real-time data on pedestrian movement, supporting smart city development and efficient space utilization. Overall, this approach aims to enhance energy efficiency while reducing dependency on conventional power sources.

V. Design Concepts Going to be Used

The project is designed to convert mechanical energy (pressure or vibration) into electrical energy using a piezoelectric disc. When force is applied to the disc, it generates a small AC voltage. This AC output is passed through a bridge rectifier made using four 1N4007 diodes, which converts the signal to DC voltage. A capacitor and resistor are used to filter and smooth the output, ensuring stable voltage is available for sensing. This DC voltage is then fed into the analog input pin A0 of an Arduino Uno, which continuously monitors the voltage level. Based on a predefined threshold, the Arduino makes decisions. If the input voltage exceeds the threshold (indicating a valid pressure event), it sends a HIGH signal to digital pin 8 to activate a BC547 transistor. The transistor acts as a switch and allows current to flow, thereby turning ON a connected bulb. At the same time, the Arduino communicates with an I2C-based LCD display, showing real-time data such as the piezo voltage and bulb status. The LCD is connected using pins A4 (SDA) and A5 (SCL). The overall concept combines energy harvesting, threshold detection, transistor switching, and realtime monitoring, making it suitable for smart control and automation applications like footstep power systems, intelligent lighting, or smart surfaces [9][10].

VI. Algorithm / Flow Chart / DFD

The overall working principle of the mini-project work has to be present here. The working principle of this project is based on the piezoelectric effect, where a piezoelectric disc generates electrical energy when mechanical pressure is applied to it. This pressure-induced vibration creates an alternating (AC) voltage output from the piezo disc. Since the Arduino and other components require direct current (DC), the AC voltage is passed through a bridge rectifier using four 1N4007 diodes to convert it into pulsating DC. A capacitor-resistor filter is then used to smooth the output and remove ripples, producing a steady voltage. This filtered voltage is connected to the analog pin A0 of the Arduino Uno, which continuously reads the signal. The Arduino compares the piezo voltage against a set threshold value. If the voltage is higher than the threshold, it sends a HIGH signal to digital pin 8, which drives the BC547 transistor into conduction. This transistor acts as an electronic switch and allows current to flow through the connected bulb, turning it ON. At the same time, an I2C LCD display connected to the Arduino shows real-time piezo readings and the ON/OFF status of the bulb. If the voltage falls below the threshold, the bulb turns OFF, and the LCD updates accordingly. This system effectively demonstrates how pressure can be converted into electrical signals and used for intelligent control applications [11][12].

VII. Proposed Block Diagram and Circuit Diagram

In this section, draw the block-diagram used or the circuit diagram that you have used in the project and explain in brief the diagram with all the components involved in it. A brief explanation about block diagram and working principle of mini-project should be presented here. The Fig. 2 gives the block-diagram of the proposed methodology of the mini project work [13][14].

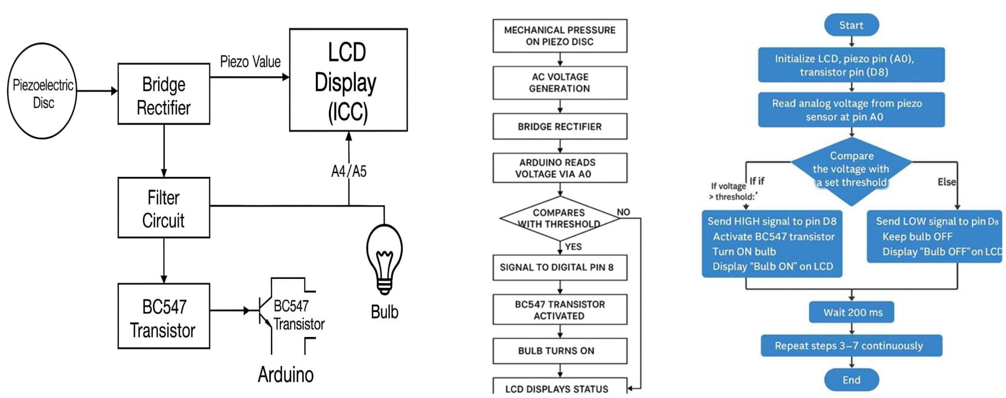

Figure 1. Flow-chart of the methodology used & the block-diagram of the proposed methodology

- Block 1 gives the information about piezo electric disk
- Block 2 gives the information about Bridge rectifier
- Block 3 gives the information about LCD Display
- Block 4 gives the information about Filter circuit

➢ Block 5 gives the information about BC547 transistor

The overall circuit diagram of the proposed undergraduate mini-project work is shown in the Fig. 2. (Detailed explanation to be presented regarding design, how the circuit works, etc…) [15][16].

VII. Proposed Research Methodology

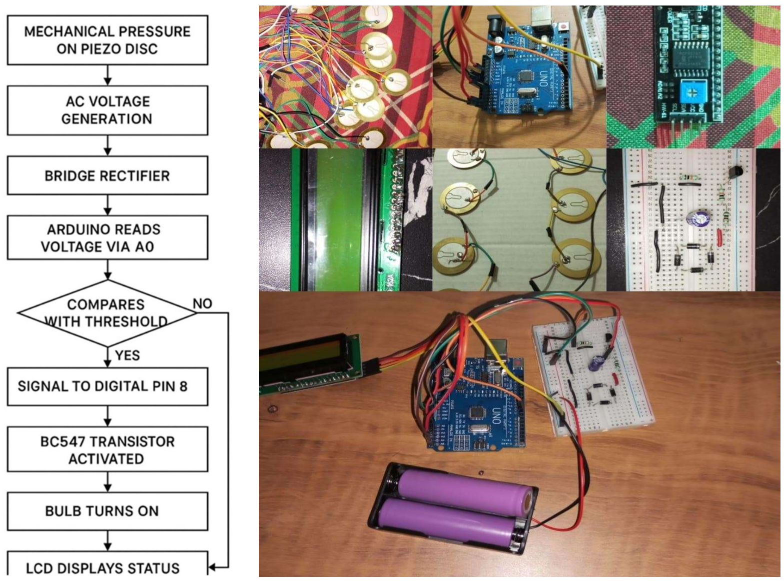

Fig. 2: Snapshot of the project work done & implemented & Flow-chart of the methodology used

The Fig. 2 gives the snapshot of the project work done & implemented & flow-chart of the methodology used. The project began with selecting the required components: a piezoelectric disc, four 1N4007 diodes for a bridge rectifier, a capacitor and resistors for filtering, a BC547 NPN transistor for switching, an Arduino Uno microcontroller, an I2C LCD display, and a small DC bulb. The piezo disc was connected to the bridge rectifier to convert the AC voltage generated by mechanical pressure into DC. A capacitor resistor network was added to smooth the output voltage. This filtered voltage was then connected to analog pin A0 of the Arduino. The Arduino was programmed to read the piezo voltage and compare it with a set threshold. If the voltage exceeded the threshold value, the Arduino sent a HIGH signal to digital pin 8, which activated the BC547 transistor. This allowed current to flow through the bulb, turning it ON. The status of the piezo voltage and the bulb was also displayed on an I2C-based LCD connected to pins A4 (SDA) and A5 (SCL). The entire setup was assembled on a breadboard, and the system was powered using the Arduino's 5V and GND lines. After building the circuit, it was tested by applying pressure to the piezo disc and observing the response on the bulb and LCD. Adjustments were made to the threshold in the code to match real-world sensitivity. The methodology ensured a step-by-step approach to building a working energy-harvesting and control system using simple, lowcost components. The development of this project follows a systematic approach to design, assemble, and test a system that converts mechanical energy from footsteps into usable electrical energy using piezoelectric technology [17][18].

VIII. Overall Working of the Project

The project is designed to demonstrate energy harvesting and intelligent control using a piezoelectric disc and an Arduino-based switching system. When pressure is applied to the piezo disc—such as by a footstep—it generates a small AC voltage due to the piezoelectric effect. This AC voltage is converted into DC using a bridge rectifier made from four 1N4007 diodes. The output is then filtered with a capacitor-resistor network to provide a stable voltage. This filtered voltage is fed to the analog pin A0 of the Arduino Uno, which reads the input and compares it against a predefined threshold level. If the sensed voltage is greater than the threshold, it indicates a valid pressure event. The Arduino then sends a HIGH signal from digital pin 8 to activate a BC547 NPN transistor, which acts as a switch and turns ON a connected bulb. At the same time, the Arduino sends data to an I2C LCD display, showing the real-time piezo voltage and bulb status (ON/OFF). If no pressure is applied or the voltage is below the threshold, the bulb remains OFF. This system effectively converts mechanical energy into a usable signal for automation, providing a low-cost, real-time, and interactive control solution that can be applied in smart footpaths, energy-saving devices, or human-triggered lighting systems [19].

IX. Experimental Results

The project was implemented successfully using both simulation and experimental methods. When pressure was applied to the piezoelectric disc, it generated a small AC voltage, which was converted to DC using a bridge rectifier. The filtered DC voltage was then processed by the Arduino Uno, which accurately read the analog input through pin A0. In real-time testing, when the piezo output exceeded the threshold (typically around 2–3V depending on the pressure), the Arduino sent a signal to activate the BC547 transistor, which in turn switched ON the bulb. The LCD display effectively showed the live piezo voltage and updated the bulb status to ON or OFF based on the input [20].

X. Conclusions

In conclusion, footprint power generation using piezoelectric plates represents a forward-thinking and environmentally conscious approach to addressing the growing demand for sustainable energy. By capturing the mechanical energy produced by human footsteps and converting it into electrical power, this technology makes effective use of an abundant and otherwise wasted energy source. It is especially suited for high-traffic urban environments such as train stations, shopping malls, schools, and public walkways, where the constant movement of people can be harnessed to generate electricity for lighting, sensors, and other low-power applications. Beyond its practical benefits, this form of energy harvesting promotes greater awareness of renewable energy technologies and encourages innovation in smart city infrastructure. The integration of piezoelectric systems into everyday settings not only helps reduce reliance on fossil fuels but also supports the creation of intelligent systems that can monitor foot traffic and improve energy efficiency. While it may not yet be a large-scale power solution, its scalability, low maintenance, and eco-friendly nature make it a valuable complementary energy source. As research and development continue to advance, footprint power generation has the potential to play a significant role in the future of urban sustainability and green technology.

References

[1] Sakthivel, M, et al. "Brand Loyalty through AI and Personalisation AI-Generated Content for Financial Marketing." In Intersecting Natural Language Processing and FinTech Innovations in Service Marketing, edited by Arjun J Nair, et al., 77-96. Hershey, PA: IGI Global Scientific Publishing, 2025. https://doi.org/10.4018/979-8-3693-9944-6.ch006

[2] Sreekanthaswamy, Nikitha, et al. "Digital Tools and Methods." In Enhancing School Counseling With Technology and Case Studies, edited by Eriona Çela, et al., 25-48. Hershey, PA: IGI Global Scientific Publishing, 2025. https://doi.org/10.4018/979-8-3693-8392-6.ch002

[3] P. K., Ranjitha, et al. "Transportation Challenges In Islands Tourism." In Navigating Mass Tourism to Island Destinations: Preservation and Cultural Heritage Challenges, edited by Viana Imad Hassan, 287-312. Hershey, PA: IGI Global Scientific Publishing, 2025. https://doi.org/10.4018/979-8-3693-9107-5.ch011

[4] Mehta, Arvinder Kour, et al. "Teaching Methods: Techniques for Disadvantaged Learners." In Mitigating Learner Disadvantages in Teaching and Learning, edited by Shalin Hai-Jew, 181-206. Hershey, PA: IGI Global Scientific Publishing, 2025. https://doi.org/10.4018/979-8-3693-8623-1.ch007

[5] Subramanian, Malini, et al. "Assessment and Evaluation in Personalized STEAM Education." In Integrating Personalized Learning Methods Into STEAM Education, edited by Nguyen Duc Son, 103-122. Hershey, PA: IGI Global Scientific Publishing, 2025. https://doi.org/10.4018/979-8-3693-7718-5.ch005

[6] Shashank G & et.al. : The evolution of smart urban mobility with emerging technologies. Leveraging VANETs and Blockchain Technology for Urban Mobility, IGI Book Chapter, 1-27. (2025) DOI: 10.4018/979-8-3373-0265-2.ch001

[7] Saravanan A. & et.al. : Mental health challenges and solutions in high-pressure work environments, Innovative Approaches to Managing Conflict and Change in Diverse Work Environments, IGI Book Chapter, 247 – 271 (2025). DOI: 10.4018/979-8-3693-9556-1.ch011

[8] Satvik Kusagur & et.al., “Modelling of smart intelligent materials with PZT & PVDF sensors/actuators to control the active vibrations of flexible aluminum mechanical cantilever beams using proportional integral derivative (PID) techniques”, Elsevier Materials Today Proceedings, 2020, Vol. 37, Part 2, pp. 2075-2082, 2021, https://doi.org/10.1016/j.matpr.2020.07.507

[9] Pritosh Tomar, Prateek Chauhan, Ashwani Kumar, Kumar A., Anoop Kumar Shukla, Víctor Daniel Jiménez Macedo, Bajarang Prasad Mishra, Nageswara Rao Lakkimsetty, Tadaga Channaveerappa Manjunath, “Numerical Investigation of Thermal Performance Enhancement of Solar Reservoir using Flash Cycle”, Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, vol. 123, no. 1, pp. 197–221, Nov. 2024 DoI : https://doi.org/10.37934/arfmts.123.1.197221

[10] M. Akshatha Rao & et.al., "Automated detection of diabetic retinopathy through image feature extraction," Int. Conf. on Advan. in Electron. Compu. & Communi., Reva Univ., Bangalore, India, pp. 1-6, 10-11 Oct. 2014, https://doi.org/10.1109/ICAECC.2014.7002402

[11] Ranjitha P.K., Selvakumar P., Anute, Nilesh, Manjunath T.C., Sureshkrishna G., Pougajendy S., "Transportation challenges in Islands tourism", in Navigating Mass Tourism to Island Destinations: Preservation and Cultural Heritage Challenges", IGI Global Scientific Publishing, Book Chapter 11, pp. 287 – 311, 2025, DOI: 10.4018/979-8-3693-9107-5.ch011

[12] Selvakumar P., Rajlakshmi P.V., Manjunath T.C., Subramanian, Malini, Portia R., Mishra Biswo Ranjan Ranjan, "Assessment and evaluation in personalized STEAM education", in Integrating Personalized Learning Methods Into STEAM Education, IGI Global Scientific Publishing, Book Chapter 5, pp. 103-122, 2025, DOI: 10.4018/979-8-3693-7718-5.ch005 https://doi.org/10.4018/979-8-3693-7718-5.ch005

[13] Shubhangi Joshi & et.al., "New Approach of Steganographic Design of Speech Signals & its Application to Voice Recognitions," IEEE 7th Int. Conf. for Converg. in Technol. (I2CT), Mumbai, India, pp. 528-532, 7-9 Apr. 2022, https://doi.org/10.1109/I2CT54291.2022.9825419

[14] K.M. Arunkumar & et.al., "Vibration signal analysis using time and time frequency domain: Review," IEEE Int. Conf. on Power, Control, Signals & Instru. Engg.(ICPCSI), Saveetha Engineering College, Chennai, India, pp. 1808-1811, Sep. 2017, https://doi.org/10.1109/ICPCSI.2017.8392027

[15] Dharmanna Lamani, Ramegowda & et.al., "Fractal Dimension with Object Rotation: A Case Study with Glaucoma Eye," Fifth Int. Conf. on Signal & Image Proce., Bangalore, India, pp. 111-116, Jan. 2014, https://doi.org/10.1109/ICSIP.2014.22

[16] Bijnan Bandyopadhyay & et.al., "Fault tolerant control of flexible smart structures using robust decentralized periodic output feedback technique", IoP Science, Jour. of Smart Materials & Structures, DOI: 10.1088/0964-1726/14/4/021 Vol. 14, No. 4, 624.

[17] Bijnan Bandyopadhyay & et.al., "Smart control of cantilever structures using output feedback", Int. Jour. of Sim. : Syst., Sci. & Tech., Vol. 7, No. 4-5, pp. 51-68, 2005. EiD 2-s2.0-84924434156 https://ijssst.info/Vol-07/No-4-5/Paper7.pdf

[18] Bijnan B., et.al., "Fault tolerant control of flexible smart structures using robust decentralized fast output sampling feedback technique", Asian Journal of Control, Vol. 9, Issue 3, pp. 268-291, Sept. 2007, DOI: 10.1111/j.1934-6093.2007.tb00414.x https://doi.org/10.1111/j.1934-6093.2007.tb00414.x

[19] Shobha A.S., T.C. Manjunath, "Design & development of transmitted & encrypted datas using SDN and energy self-healing concepts used in RF energy harvesting wireless sensor nets," Third Int. Conf. on Intelli. Compg. Instru. & Contr. Technolo. (ICICICT), Kannur, India, pp. 686-689, Aug. 2022, doi: 10.1109/ICICICT54557.2022.9917923. https://doi.org/10.1109/ICICICT54557.2022.9917923

[20] Arvinder Kour Mehta, Yashoda L., Selvakumar P., Mishra, Biswo Ranjan, Abhijeet Das, T.C.Manjunath, "Teaching methods: Techniques for disadvantaged learners", In Mitigating Learner Disadvantages in Teaching and Learning, Book Chapter 7, pp. 181-206, IGI Global Scientific Publishing, 2025, DOI: 10.4018/979-8-3693-8623-1.ch007 https://doi.org/10.4018/979-8-3693-8623-1.ch007