Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/22205
DOI URL: http://dx.doi.org/10.21474/IJAR01/22205

ISSN NO. 2320-5407

RESEARCH ARTICLE

SMART ENERY HARVESTING SYSTEM USING FOOTSTEPS

G.N.S.Sree Laya, B.Vamsi, K.Thirupathi Rao, A.Vishnu Vardhan Reddy, CH.V.Srikar Dutt and M.Sukumar

1. UG Student, Dept. of Artificial Intelligence & Data Science, QIS College of Engineering and Technology (A), Ongole, Andhra Pradesh, India.

Manuscript Info

Manuscript History
Received: 04 September 2025
Final Accepted: 06 October 2025
Published: November 2025

Key words:-
Footstep Power Generation,Sustainable Energy Systems, Step Counting, Battery Storage.

Abstract

The Smart Energy Harvesting System using Footsteps presents an innovative method for sustainable power generation by converting mechanical energy from human footsteps into electrical energy. This paper reviews various energy harvesting mechanisms, with a focus on piezoelectric based systems for capturing vibration energy. The propose d system integrates a piezoelectric sensor array, smart rectifier, and DC–DC boost converter for efficient energy conversion, along with a microcontroller based power management unit for storage and utilizatio n. The harvested energy is stored in lithium ion batteries and supercapa citors, enabling applications such as low-power lighting and mobile charging. This review highlights advancements, design challenges, and optimization techniques in smart energy harvesting technologies, emphasizing their potential in developing self-powered infrastructures for smart cities and public spaces.

Introduction:-

The increasing energy demand all over the world poses a significant concern on policy makers yet the energy consumption is expected to increase by 34% by the year 2030. However, governments and policy makers are concerned with the consumption of energy from non-renewable resources that cause environmental and climate change issues. There is an increasing demand for Dail electrical energy due to the emergence of electrical and electronic devices that rely on electricity. There are clean renewable energy sources, such as sound energy, vibration energy, wind energy, sea wave energy, and kinetic energy. Proper exploitation of such sources helps reduce the burden of the increasing demand for traditional energy sources while at the same time benefiting from sources that are permanently and freely available. The smart energy refers to where energy is used in an efficient manner with the help of modern technology. There are loads of strategies to generate electricity as an alternative, and one in every of them, footstep electricity technology, may be a green manner to generate electricity. In the harvesting system the smart energy is used to convert the human produced energy in to electricity and store it, used for various purposes. The smart energy harvesting system using footsteps is used to collect the energy and stores energy from people'sfootsteps which is produced when they walk and then uses it to power things like lights, sensors, or devices etc. It has several advantages, first it is not affected by weather conditions, which can limit the output of solar and wind power. Second, footstep power generation can be implemented in various scenarios, including transportation hubs, public spaces, and personal devices, making it a versatile and accessible technology. The paper Foot Step Power Generation using Piezoelectric Sensor explains there is a system which obtains mechanical energy from the human footsteps and it converts it into electrical energy in a usable way using piezo electric sensors which is placed in the floor or tile [1]. Here an electromagnetic induction is used for conversion of mechanical energy to electrical energy [2]. The piezo electric sensors and electro mechanism are combined to increase power of overall output which results in more efficiency and durability while using the stored energy [3]. The electricity is a basic need in our daily life but continuous using of energy there is no sufficient energy. By using these piezo electric sensors, we can produce energy as much as required [4]. It tells about how the energy is stored in the batteries, How the energy is supplied through rectifiers and inverters for daily using [5].

Piezoelectric floors generate many microwatts up tomany watts per step, depending on pedestrians' s frequency and piezoelectric technology. Several feasibility studies have been proposed by [6], such as high pedestrian public space and low pedestrian private space. Another report that is [7] shows that piezoelectric pavement can also be design for intelligent road and all kind of information board, light, etc. All of this possibility begins with scavenging the human activities [8]. Another application of piezoelectric energy harvester found in. The idea still using piezoelectricity phenomenon when it got pressed or vibrated by raindrops, vibration, pavement pressure, highway pressure etc [9]. It is possible to generate higher power by connecting multiple piezoelectric energy harvesters. However, piezoelectric energy harvester cannot be directly connected to electrical loads because the high output voltage changes based on how people walk and how much pressure there is over time. Furthermore, a simple full-wave bridge rectifier is insufficient because of the unstable waveform that results from the rectification stage. As a result, a suitable control circuit is needed to solve these problems [10]. This study examines the practicality of producing power from piezoelectric crystals and provides a detailed plan for the mechanical and electrical components of the proposed energy harvesting system.

Some Common Mistakes:

- Low Power Output per Step
- A single piezoelectric disc generates only a few milliwatts.
- Requires many discs to achieve usable power.
- Unstable Voltage
- The generated voltage fluctuates with weight, step force, and walking pattern.
- Cannot be directly stored in batteries without regulation.
- Durability of Piezo Discs
- Continuous mechanical stress reduces lifespan.
- Discs can crack or degrade under heavy load.
- High Initial Cost
- Embedding hundreds of piezo sensors in public walkways is expensive.
- Maintenance cost is also high.
- Energy Conversion Efficiency
- Mechanical-to-electrical conversion is not 100% efficient.
- Losses occur in rectification, regulation, and storage.
- Limited Practical Load
- Base papers only demonstrate powering LEDs or a single bulb.
- Not sufficient for large-scale power requirements.

Methodology:-

The proposed system is designed to efficiently convert mechanical energy from footsteps into usable electrical energy, regulate it for stable storage, and monitor the output in real time using a microcontroller.Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

A. Energy Generation Using Piezoelectric Sensors:-

The system employs multiple piezoelectric discs placed beneath a stepping platform. Piezoelectric materials possess the unique property of generating electrical charges when subjected to mechanical stress. When a person walks on the platform, the downward force from the foot compresses the piezoelectric discs, producing an alternating voltage signal. However, a single disc produces only a few millivolts to volts, which is insufficient for direct use. To overcome this limitation, several discs are connected in series–parallel configuration. Series connection increases the output voltage.Parallel connection increases the output current.This combination ensures that the overall electrical energy generated per step is maximized.

Rectification and Voltage Regulation:-

The raw output from piezoelectric sensors is irregular AC with fluctuating amplitude. This cannot be directly stored in batteries. Therefore, the output is passed through a bridge rectifier circuit (using diodes such as 1N4007) to convert AC into DC. A smoothing capacitor is connected across the rectifier to filter ripples and produce a more stable DC output. Since the magnitude of generated DC still varies depending on the force of footsteps, a buck–boost converter (XL6009 module**)** is used to regulate the voltage. The buck–boost converter ensures that even when the input fluctuates, the output remains stable at the required charging level. This stage is critical because stable and consistent voltage enhances battery life and prevents undercharging or overcharging.

Energy Storage Mechanism:-

The regulated DC power is directed into a dual-battery arrangement. 4V Rechargeable Battery: Acts as the primary buffer, storing initial harvested energy. 12V Rechargeable Battery. Receives power from the regulated stage for larger storage capacity and to support higher loads. This two-tier storage system ensures that the small but continuous energy harvested from footsteps accumulates effectively. The 12V battery becomes the main power reservoir, capable of supplying energy to both DC and AC loads.

Power Utilization:-

The harvested and stored energy can be used in two ways. DC Loads: Low-power devices like LEDs, sensors, or charging small electronic gadgets can run directly from the 12V DC output.AC Loads: The DC energy from the battery is fed into an inverter circuit to convert it into AC (typically 230V), enabling the system to power corridor lights, fans, or other small AC appliances. This dual-load capability increases the practicality of the system by allowing it to function in multiple real-life scenarios.

Monitoring and Control using Arduino:-

An Arduino Uno microcontroller is employed for intelligent monitoring and automation. Its functions include. Step Counting: By detecting piezoelectric sensor activations, Arduino counts the number of footsteps and stores this data. Voltage Measurement: The Arduino measures the voltage generated and stored in the system. LCD Display: A 16×2 LCD module is interfaced with Arduino to display both the number of steps taken and the voltage level in real time. Automated Lighting Control**:** With the help of a relay circuit and a Light Dependent Resistor (LDR), Arduino switches on corridor lights when ambient light is low. This ensures that harvested energy is used efficiently and only when required.

System Workflow:-

The methodology can be summarized in the following step-by-step process. Human footsteps apply pressure on piezoelectric discs. Mechanical stress is converted into AC voltage through the piezoelectric effect. AC voltage is rectified and filtered into DC. Buck–boost converter regulates voltage to a stable level. Energy is stored in dual batteries (4V and 12V). That stored DC energy powers DC loads directly or AC loads through an inverter. The Arduino monitors step count and voltage, displaying them on an LCD. Relay and LDR enable automated lighting control, conserving stored energy.The mathematical representation of the proposed footstep power generation system is based on the principles of piezoelectricity, power conversion, energy storage, and monitoring. The following equations define the working of each stage of the system.

Mathematical Model:-

The mathematical representation of the proposed footstep power generation system is based on the principles of piezoelectricity, power conversion, energy storage, and monitoring. The following equations define the working of each stage of the system.

Piezoelectric Energy Generation:

When a force F is applied on the piezoelectric material, it generates charge QQQ given by:

$Q=d\times F$ (1)

where d is the piezoelectric constant (C/N). The voltage generated across the piezoelectric disc is expressed as:
$V = \frac{Q}{C}$ (2)
where CCC is the capacitance of the piezoelectric element.

Power and Energy Relations:
The power generated by the piezoelectric sensor is:
$P = V \times I$ (3)

The energy stored in the capacitor during filtering is:
$E_C = \frac{1}{2} cv^2$ (4)

The energy stored in the rechargeable battery is:
$E_b = v \cdot I \cdot t$ (5)

Buck–Boost Converter:
The buck–boost converter regulates unstable voltage from piezo discs. Its input–output relation is:
$v_{out} = -D \times \frac{v_{in}}{1-D}$ (6)
where D is the duty cycle of the PWM signal.

Inverter Output:
The RMS value of the AC voltage obtained from the inverter is:
$v_{Ac(rms)} = \frac{v_{DC}}{\sqrt{2}}$ (7)

Step Counting and Monitoring:
The total number of footsteps recorded by Arduino is:
$N = \sum_{1=j}^{k} \delta i$ (8)
where δi=1 if a footstep is detected, else 0.

Efficiency of the System:
The overall efficiency of the energy harvesting system is:
$\eta = \frac{P_{Out}}{p_{In}}$ (9)

System Architecture:-
The proposed system for footstep power generation is designed to harvest energy from human walking activity, regulate it for stable storage, and utilize it effectively for powering loads. The architecture is composed of five primary stages.

Piezoelectric Energy Harvesting:
Piezoelectric discs are embedded under a stepping platform. When force is applied due to footsteps, the discs generate an alternating voltage based on the piezoelectric effect. To enhance output, the discs are arranged in a series–parallel configuration, thereby improving both voltage and current.

Rectification and Filtering:
The raw AC voltage from the piezoelectric sensors is irregular and unsuitable for direct use. A full-bridge rectifier converts the AC into DC, while a capacitor filter reduces ripples and provides smoother output.

Voltage Regulation with Buck–Boost Converter:
The DC voltage still fluctuates depending on step force. A buck–boost converter stabilizes this voltage to a desired level, ensuring consistent charging of the storage batteries.

Dual-Battery Energy Storage:
A dual-battery arrangement is adopted for efficient energy storage. The initial energy is stored in a 4V rechargeable battery, and through regulation, it is transferred to a 12V battery that acts as the main storage unit. This arrangement ensures reliability and maximizes the use of harvested energy.

Utilization through Inverter and Loads:
The stored DC energy is used in two ways:
Directly powering DC loads such as LEDs and low-power electronics. Feeding an inverter to obtain AC supply (230V), which can be used for corridor or street lighting.

Monitoring and Control using Arduino:-
An Arduino Uno microcontroller is employed to monitor and control the system. It records the number of footsteps, measures the generated voltage, and displays these parameters on a 16×2 LCD module. Additionally, with the help of a relay and light-dependent resistor (LDR), Arduino enables automated control of corridor lighting based on ambient conditions, thereby improving system efficiency.Several studies have explored piezoelectric energy harvesting through footstep power generation. Shwetha J. et al. (2022) implemented a setup with 16 piezo sensors connected in series, using a rectifier to charge a 12V battery and an inverter to power a 100W bulb. However, their system lacked voltage stability and monitoring features. Similarly, M. N. Fakhzan et al. (2004) utilized piezoelectric vibration harvesting with battery storage, but each sensor provided very low output, limiting applications to small electronic devices. Shraddha P. et al. (2020) proposed an RFID-based smart footstep harvesting system, which was constrained to ID-specific uses, such as smart campus charging. Gopinath R. et al. (2018) combined piezo sensors with a treadmill setup for indoor gym energy harvesting, but their design suffered from mechanical losses and bulkiness.In comparison, the proposed method enhances the energy harvesting system with a more efficient and scalable design. It uses a series–parallel network of piezo discs instead of a simple series configuration, improving output consistency. A Buck–Boost converter is introduced to regulate the voltage more effectively, and energy is stored across two batteries (4V and 12V) rather than one. The use of an Arduino Uno with an LCD display enables real-time monitoring of both voltage and step count, addressing the lack of monitoring in previous designs. Unlike earlier methods that were either unstable or application-specific, the proposed system is stable, smart, and scalable—suitable for powering corridor or street lights and providing charging ports in public spaces.

Block-Diagram:-

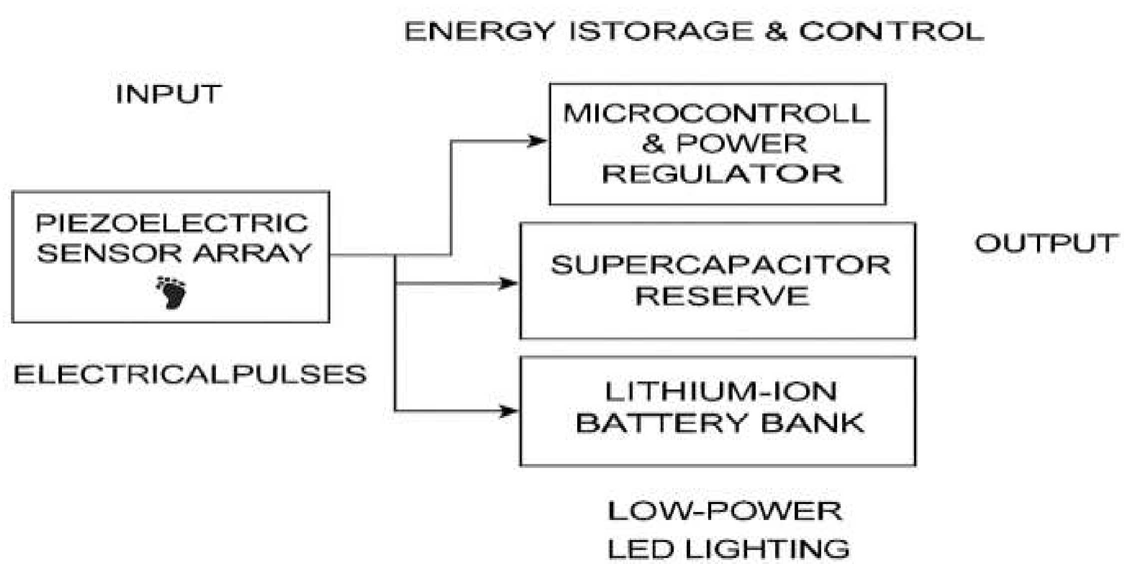

Fig-1: Block diagram

Result:-

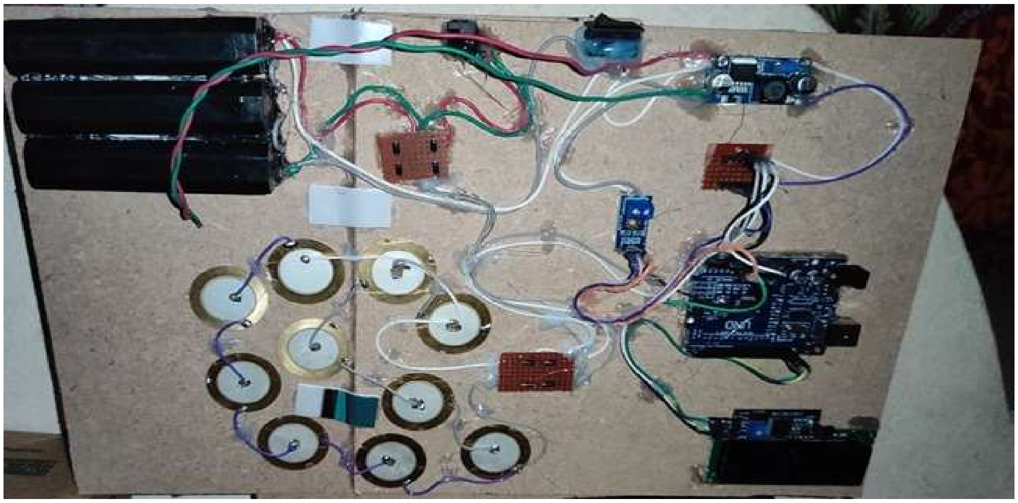

Fig-2: Result Image

The Smart Energy Harvesting System using Footsteps is an innovative approach to generating clean and renewable energy from everyday human movement. This system works by converting the mechanical energy produced when people walk into usable electrical energy through specially designed piezoelectric or pressure-sensitive sensors embedded in the floor. Every step taken applies pressure to these sensors, which generate a small amount of electricity that is then collected and stored in a rechargeable battery.The stored energy can be used to power low-energy devicessuch as LED lights, digital displays, or even charge mobile phones. In high-footfall areas like shopping malls, railway stations, schools, or stadiums, this technology can collectively produce a meaningful amount of power, helping to light up corridors or charge emergency systems.Beyond its technical capability, this system offers a sustainable and eco-friendly solution to modern energy challenges. It reduces reliance on traditional fossil fuels and promotes the concept of green energy generation through simple, everyday activities. Because it makes use of existing human movement, it is also cost-effective and low- maintenance.

Conclusion:-

The Smart Energy Harvesting System using Footsteps effectively demonstrates how mechanical energy from human motion can be converted into useful electrical energy. By utilizing piezoelectric sensors and efficient power conversion circuits, the system provides a sustainable way to generate and store energy. The stored power can be used for applications such as LED lighting and mobile charging, reducing dependency on conventional power sources. This project highlights an innovative and eco-friendly approach to renewable energy generation, making it ideal for implementation in crowded public areas like railway stations, malls, and sidewalks.

References:-

[1] Shwetha J., Sushma H. P., Vijay V., and Prathibha S., "Foot Step Power Generation using Piezoelectric Sensor," International Journal of Engineering Research & Technology (IJERT), vol. 10, no. 11, pp. 1–4, Nov. 2022.
[2] M. N. Fakhzan and Asan G. A. Muthalif, "Vibration Based Energy Harvesting Using Piezoelectric Material," IEEE Transactions on Industrial Electronics, vol. 52, no. 4, pp. 1131–1142, Aug. 2004.
[3] Shraddha P., Pratik B., and Hemant C., "Advanced Foot Step Power Generation System using RFID for Charging," International Research Journal of Engineering and Technology (IRJET), vol. 7, no. 5, pp. 2769–2773, May 2020.
[4] Gopinath R., Lavanya M., and Arivalagan M., "Power Generating using Human Foot Step with Piezo Electric Sensor and Treadmill," International Journal of Pure and Applied Mathematics (IJPAM), vol. 119, no. 15, pp. 655–662, 2018.
[5] Rahul J., Rahul S., and Sunil K., "Energy Harvesting from Human Footstep Using Piezoelectric Effect," International Journal of Advance Research in Science and Engineering (IJARSE), vol. 7, no. 3, pp. 122–129, 2018.
[6] S. S. Patil and P. S. Joshi, "Piezoelectric Power Generation through Footstep," International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), vol. 6, no. 4, pp. 465–470, Jul.–Aug. 2019.

[7] Ankit Kumar and Neha Sharma, "Design and Fabrication of Piezoelectric Energy Harvesting System for Smart City Applications," International Journal of Recent Technology and Engineering (IJRTE), vol. 8, no. 6, pp. 2011–2016, Mar. 2020.
[8] J. Thomas, K. Rajesh, and P. Devi, "A Review on Footstep Power Generation System," International Journal of Electrical Engineering and Technology (IJEET), vol. 11, no. 3, pp. 45–55, 2020.
[9] R. Singh and A. Verma, "Generation of Electricity through Footsteps using Piezoelectric Materials," International Journal of Emerging Technologies in Engineering Research (IJETER), vol. 6, no. 8, pp. 98–103, Aug. 2018.
[10] K. Anusha, B. Sridhar, and G. Reddy, "Design of Foot Step Power Generation System Using Piezoelectric Sensors," International Journal of Engineering and Advanced Technology (IJEAT), vol. 9, no. 2, pp. 376–381, Dec. 2019.