International Journal of Scientific Research & Engineering Trends
Volume 12, Issue 1, Jan-Feb-2026, ISSN (Online): 2395-566X

Application Of Piezoelectric Powered Floor In India To Efficiently Increase Electricity Generation

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Abstract- — Rising electricity demand and the need for sustainable energy solutions have encouraged exploration of alternative micro-generation technologies. This study investigates the use of piezoelectric powered flooring systems to harvest mechanical energy from human footsteps in high-footfall areas such as railway stations, commercial buildings, and educational institutions in India. By converting mechanical stress into electrical energy, piezoelectric materials offer a method of generating supplementary power without requiring additional land or fuel resources. The proposed work presents the system design framework, working principle, and feasibility of large-scale implementation within public infrastructure. Performance estimations indicate that although piezoelectric flooring cannot replace conventional energy sources, it can contribute to localized power needs and support smart, energy-efficient urban environments. The study highlights the potential of integrating energy harvesting technologies into everyday infrastructure to promote sustainable development.

Keywords: Piezoelectric energy harvesting, Smart flooring systems, Renewable micro-generation, Sustainable urban infrastructure, Footstep power generation, Decentralized energy, India.

I. INTRODUCTION

The rapid growth of urbanization and population in developing countries like India has led to a significant rise in electricity demand. Conventional power generation methods, heavily dependent on fossil fuels, continue to contribute to environmental degradation and greenhouse gas emissions. Although large-scale renewable energy sources such as solar and wind power are expanding, there remains a need for complementary micro-generation solutions that can be integrated directly into everyday infrastructure. Harvesting small amounts of energy from routine human activities represents one such promising approach.

Human locomotion is a continuous and largely untapped source of mechanical energy. In densely populated regions such as railway stations, metro platforms, shopping malls, educational institutions, and public walkways, thousands of footsteps exert mechanical pressure on the ground every day. This otherwise wasted mechanical energy can be converted into electrical energy using piezoelectric materials, which generate an electric charge when subjected to mechanical stress. The integration of piezoelectric technology into flooring systems provides an opportunity to develop smart, energy-producing surfaces without altering user behavior or requiring additional fuel resources.

Piezoelectric energy harvesting has been widely explored at small scales for powering low-energy devices, sensors, and wireless systems. However, its application in large-scale public infrastructure, especially in high-footfall environments within developing nations, remains relatively underexplored. India, with its vast population density and expanding urban infrastructure, presents a unique environment where even low per-step energy output can accumulate into meaningful supplementary power generation. When strategically installed in high-traffic areas, piezoelectric floors can contribute to decentralized energy production while also promoting awareness of sustainable technologies among the public.

Beyond energy generation, piezoelectric flooring systems offer additional advantages such as modular installation, minimal visual impact, and compatibility with smart city initiatives. These systems can be integrated with energy storage units and low-power applications such as lighting, display systems, and environmental sensors, thereby reducing reliance on grid electricity for localized needs. At the same time, challenges related to conversion efficiency, durability under repeated loading, and economic feasibility must be addressed for practical large-scale deployment.

This study proposes the design and application framework of a piezoelectric powered flooring system tailored for Indian conditions. The research focuses on system design considerations, expected energy output under typical footfall patterns, and the potential role of such systems in supporting sustainable urban energy solutions. By evaluating both technical feasibility and implementation prospects, this work aims to contribute toward the development of innovative, infrastructure-embedded renewable energy technologies.

II. LITERATURE SURVEY:

Zhang et al. present a novel piezoelectric wave energy converter aimed at addressing the power supply challenges of low-power electrical devices deployed on cross-sea bridges. Traditional wave energy conversion systems are often unsuitable for such applications due to their large size, structural complexity, and high maintenance requirements. To overcome these limitations, the authors propose a compact point-absorbing device that converts wave-induced vertical motion into usable electrical energy. The system employs a mechanical rectification power take-off mechanism that transforms bidirectional wave motion into unidirectional rotation, enabling stable and efficient energy conversion under irregular sea conditions.

A key contribution of the study lies in the integration of a magnetic–piezoelectric coupling mechanism, where rotating magnets periodically excite piezoelectric beams to generate electrical output. The authors develop a comprehensive theoretical model based on hydrodynamic analysis and validate it through experimental testing using a 3D-printed prototype. The results demonstrate consistent voltage generation suitable for powering low-energy electronic devices, highlighting the feasibility of piezoelectric-based wave energy solutions for marine infrastructure monitoring. This work significantly advances small-scale wave energy research by improving efficiency, durability, and adaptability compared to existing approaches.

III. PROPOSED SYSTEM :

The proposed system is designed to utilize the mechanical energy generated through routine human locomotion, such as walking, running, and jumping, and convert it into usable electrical power. In urban environments, a significant amount of mechanical energy is continuously produced in high-footfall areas including sidewalks, railway platforms, campuses, shopping complexes, and recreational zones. This energy is typically dissipated into the ground without any form of utilization.

The proposed approach aims to capture this otherwise wasted energy in a passive and unobtrusive manner, ensuring that normal pedestrian movement is not affected. At the core of the proposed system is an arrangement of piezoelectric elements placed beneath a mechanically robust top plate. When a person steps on the surface, the applied pressure induces mechanical stress on the piezoelectric elements, resulting in the generation of electrical voltage. The mechanical structure is carefully designed to distribute force uniformly across the elements, thereby enhancing energy generation while also improving durability under repeated loading. Protective layers are incorporated to prevent damage due to excessive force and to maintain user comfort during operation.

The electrical output obtained from the piezoelectric elements is inherently alternating and irregular in nature due to variations in human movement. To address this, a bridge rectifier is used to convert the alternating output into direct current. This is followed by a voltage regulation stage that stabilizes the output to a level suitable for storage and utilization. The regulated energy is stored in a rechargeable battery or supercapacitor, allowing energy accumulated from multiple footsteps to be used continuously for powering connected loads.

To demonstrate the practical viability of the proposed system, the stored energy is utilized to operate low-power devices such as LED lighting, display indicators, or sensor-based modules. The system is designed with modularity in mind, enabling scalability by increasing the number of piezoelectric elements or installation area based on footfall density and application requirements. By addressing challenges related to energy output consistency, durability, and integration with existing infrastructure, the proposed system offers a practical and sustainable solution for leveraging human locomotion as a supplementary energy source in modern urban environments.

IV. PROPOSED SYSTEM EXPLANATION :

The proposed system aims to overcome the limitations of existing footstep energy harvesting technologies by designing a scalable, modular, and application-oriented piezoelectric flooring solution suitable for Indian urban environments.

V. WORKING PRINCIPLE :

The system is based on the piezoelectric effect, where certain materials generate electrical charge when subjected to mechanical stress.

When a person walks on the flooring surface:

- Mechanical pressure is applied to the top plate.
- The force is transferred uniformly to the piezoelectric elements placed beneath.
- The piezoelectric elements deform due to applied stress.
- Deformation generates alternating electrical voltage.

- The AC voltage is converted into DC using a bridge rectifier.
- A voltage regulation circuit stabilizes the output.
- The regulated energy is stored in a rechargeable battery or supercapacitor.
- The stored energy powers low-power devices such as LEDs or sensors.

VI. EXISTING SYSTEM :

Existing methods for utilizing energy generated from human locomotion are largely based on the conversion of mechanical energy produced during activities such as walking, running, or jumping into electrical power. Most existing solutions rely on piezoelectric materials, which generate an electric charge when subjected to mechanical stress. These materials are commonly embedded beneath floor panels, pavements, or platforms placed in high-footfall areas such as public walkways, railway stations, and institutional campuses. In addition to piezoelectric approaches, some studies have investigated electromagnetic and triboelectric techniques, where relative motion or surface interaction is used to induce electrical output. These methods are typically evaluated through small-scale prototypes or laboratory-based experimental setups.

Although existing solutions demonstrate the feasibility of generating electricity from human movement, their practical effectiveness remains limited. The electrical output generated per individual footstep is relatively low and often inconsistent due to variations in pedestrian weight, walking speed, and force applied. To compensate for this, existing designs require a large number of conversion elements, which increases system complexity and cost. Moreover, durability is a major concern, as continuous repetitive loading can lead to material fatigue and reduced performance over time. Many existing implementations also face challenges related to integration with existing infrastructure, user comfort, and long-term maintenance. These limitations indicate that while current approaches provide a strong conceptual foundation, there is a need for improved designs that enhance efficiency, reliability, and scalability for real-world urban deployment.

VII. DRAWBACKS OF EXISTING SYSTEM :

- Generates very low power per footstep.
- Output is inconsistent due to variation in walking speed and force.
- Requires many piezo sensors, increasing cost and complexity.
- Piezo materials may degrade under repeated heavy loading.
- Energy losses occur during rectification and storage.
- Difficult to scale for large public infrastructure.

VIII. COMPONENTS:

The implementation of the human locomotion–based energy generation project involves a combination of mechanical, electrical, and electronic components designed to efficiently convert footstep-induced mechanical energy into usable electrical power. The key components used in this project are described below.

Piezoelectric Sensors

Piezoelectric sensors form the core energy conversion element of the project. These sensors generate an electrical charge when subjected to mechanical stress or pressure caused by human movement such as walking or jumping. Multiple piezoelectric elements are arranged strategically to maximize voltage generation under varying load conditions.

Mechanical Base and Top Plate

A sturdy mechanical base and top plate are used to transfer and distribute the applied foot pressure uniformly across the piezoelectric sensors. This structure ensures effective force transmission while maintaining user comfort and protecting the sensors from excessive stress.

Bridge Rectifier

Since the electrical output from piezoelectric sensors is alternating in nature, a bridge rectifier is employed to convert the generated AC voltage into a unidirectional DC output suitable for storage and further processing.

Voltage Regulation Circuit

A voltage regulation circuit is used to stabilize the fluctuating voltage produced during human movement. This ensures a consistent and safe voltage level for charging energy storage devices and powering low-voltage applications.

Energy Storage Unit

The generated electrical energy is stored using rechargeable batteries or supercapacitors. The storage unit allows the intermittent energy produced by footsteps to be accumulated and utilized continuously for powering low-power devices.

Load (Output Device)

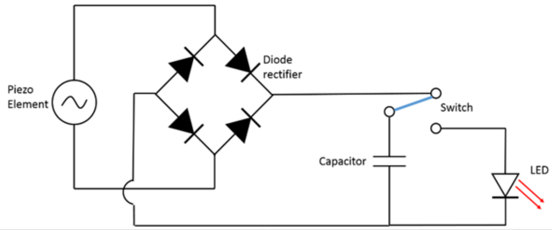
Low-power loads such as LEDs, display units, or sensor modules are connected to demonstrate practical utilization of the generated energy. These loads provide visual or functional feedback on energy generation.

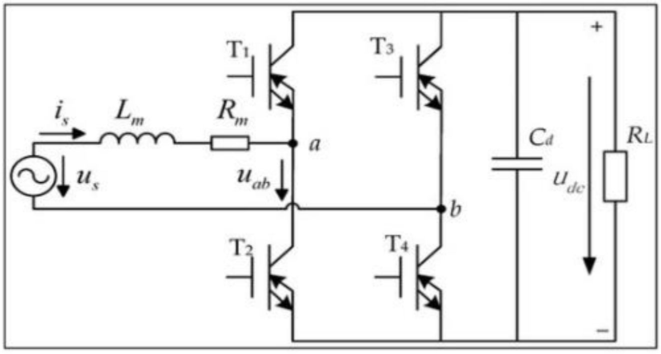
Connecting Wires and Supporting Electronics
Electrical wires, connectors, diodes, resistors, and capacitors are used to interconnect various components and ensure smooth operation of the circuit.

IX. ARCHITECTURE DIAGRAM:
X.

Human locomotion activities such as walking and jumping provide the mechanical input to the system. The applied pressure is transferred through a top plate to piezoelectric elements placed beneath it. Piezoelectric elements convert mechanical stress into electrical energy in the form of AC voltage. A rectifier and voltage regulator convert the AC output into stable DC power. The regulated energy is stored in a battery or supercapacitor. Stored energy is used to power low-power devices such as LEDs or sensors.
To calculate how much energy is stored for each tap or press on the piezo element, measure the voltage before (V0) and the voltage after the tap (V1), and then use the following equation:

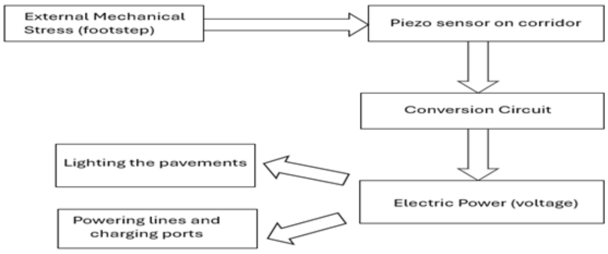
$$E_{tap} = \frac{1}{2} C (V_1^2 - V_0^2)$$





IX. Implementation :

The implementation of the proposed human locomotion–based energy generation project is carried out through a systematic integration of mechanical and electrical components. The process begins with the fabrication of a rigid base structure that serves as the foundation for mounting the energy conversion elements. A durable top plate is fixed above the base with adequate spacing to allow controlled movement when external pressure is applied. This mechanical arrangement ensures effective transfer of footstep-induced force while protecting the components from excessive stress from each step.
Piezoelectric elements are placed strategically between the base and the top plate to maximize exposure to applied pressure. Multiple elements are connected in suitable series and parallel combinations to obtain the desired voltage and current levels. The output generated from these elements varies depending on the force and frequency of human movement. The electrical connections are carefully insulated and secured to maintain reliability during continuous operation.
The alternating electrical output produced by the piezoelectric elements is fed into a bridge rectifier circuit, which converts it into direct current. A voltage regulation stage is then implemented to stabilize the fluctuating output and protect the storage and load components from overvoltage conditions. The regulated DC output is connected to an energy storage unit, such as a rechargeable battery or supercapacitor, which accumulates energy generated from repeated footsteps.
Finally, the stored energy is supplied to low-power loads such as LEDs or indicator modules to demonstrate practical energy utilization from this. In configurations where monitoring is required, a microcontroller may be integrated to observe voltage levels or display output status from the solution. The entire setup is tested under multiple varying load and movement conditions to evaluate performance, durability, and consistency. This implementation approach ensures that the system remains functional, scalable, and suitable for real-world deployment in high-footfall urban environments.



X. APPLICATION MEHODOLOGY:

To enhance electricity generation from piezoelectric flooring, the system should not only focus on material efficiency but also on where and how human movement occurs. By installing the flooring in environments that naturally create higher foot pressure, repeated impacts, or dynamic motion, the total harvested energy can be significantly increased.

Installation in High-Impact Recreational Zones

Public parks and playgrounds provide excellent opportunities for higher force application compared to normal walking.

Piezoelectric flooring can be embedded in:

- Children's play areas such as jump zones, hopscotch spaces, and activity pads
- Outdoor fitness parks where users perform jumping exercises, step aerobics, or skipping
- Sports warm-up zones in stadiums or community grounds

Jumping and running activities produce greater mechanical stress than walking, resulting in higher deformation of piezoelectric elements and increased electrical output.

Integration with Staircases and Ramps

Staircases are naturally high-pressure zones because each step involves lifting and placing body weight downward. Installing piezoelectric tiles on:

- Railway station staircases
- Foot overbridges
- Subway entrances
- Metro station stairways

can significantly improve energy generation. Descending steps, in particular, produce stronger impact forces, making them ideal for energy harvesting.

Placement in Transportation Hubs

Transport hubs experience continuous and dense pedestrian flow. Installing piezoelectric flooring at:

- Ticket counters and entry gates
- Security check queues
- Platform waiting areas
- Bus terminals and airport corridors

ensures repeated pressure from large numbers of people daily. Queue areas are especially useful because people shift their weight frequently, producing multiple micro-impacts.

Smart Flooring in Educational Institutions

Schools and colleges have predictable, high-density movement during class changes. Flooring can be placed in:

- Corridors between classrooms
- Library entrances
- Auditorium entryways
- Canteen queues

Additionally, interactive "energy tiles" can be installed where students are encouraged to step or jump, combining awareness with energy generation.

Commercial and Public Interaction Spaces

Shopping malls and exhibition centers are ideal due to heavy footfall and long operating hours. Piezoelectric floors can be installed in:

- Escalator entry/exit zones
- Food court waiting lines
- Promotional interactive floors that light up when stepped on

Interactive flooring increases user engagement, encouraging more steps and movement, which indirectly boosts energy harvesting.

Integration in Sports and Training Facilities

Sports complexes and gyms offer high-impact motion that produces stronger force compared to casual walking. Piezoelectric flooring can be used in:

- Indoor jogging tracks
- Aerobics and dance studios
- Warm-up and stretching zones
- Training drill areas

Athletic activities involve repetitive, forceful steps that can greatly increase energy output.

Deployment in Religious and Event Gathering Areas

Temples, festivals, and public events in India attract large crowds where people walk slowly but continuously over specific pathways. Installing energy-harvesting flooring in:

- Temple entry corridors
- Pilgrimage walkways
- Exhibition halls and fairs

can generate power from sustained, long-duration pedestrian movement.

Behavioral Design to Encourage Stronger Foot Interaction

Floor design can subtly influence user movement. Slightly flexible or responsive surfaces can make stepping more engaging, encouraging users to apply more pressure. Interactive lighting or feedback systems powered by the harvested energy can motivate people—especially children—to jump or step repeatedly, increasing total energy production.

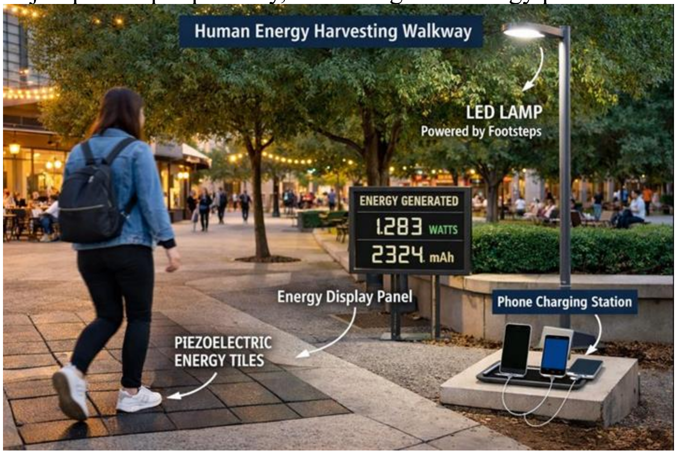


Figure 4: Implementation of Proposed solution

XI. ADVANTAGE :

- Renewable and Sustainable: Utilizes energy generated from everyday human activities such as walking and jumping, making it an environmentally friendly and renewable source of power.
- Energy from Wasted Motion: Converts mechanical energy that is otherwise lost into the ground into useful electrical energy, improving overall energy utilization.
- Suitable for Urban Areas: Highly effective in high-footfall locations like railway stations, walkways, campuses, malls, and playgrounds where human movement is continuous.
- Low Environmental Impact: Produces clean energy without emissions, noise, or pollution, contributing to sustainable urban development.
- Decentralized Power Generation: Enables localized energy generation, reducing dependency on centralized power sources for low-energy applications.
- Scalable and Modular Design: The system can be easily expanded by increasing the number of conversion elements based on foot traffic density.
- Low Maintenance: Once installed, the system requires minimal maintenance compared to conventional power generation methods.
- Educational and Awareness Value: Helps create public awareness about renewable energy and energy conservation through visible energy generation.

XII. FUTURE WORK:

The scope of this project can be extended in several directions to enhance performance, scalability, and real-world applicability. Future work may focus on improving energy output by incorporating advanced piezoelectric materials with higher sensitivity and durability. Optimizing the mechanical design to include force amplification mechanisms and adaptive surface structures can further increase the amount of electrical energy generated from each footstep.

Integration of smart electronics and communication technologies presents another promising direction. Future implementations may include microcontroller-based monitoring with wireless data transmission to track energy generation trends in real time. The generated data can be analyzed using artificial intelligence or machine learning techniques to predict footfall patterns and optimize system placement in high-traffic areas.

Large-scale deployment studies in diverse environments such as metro stations, stadiums, and playgrounds can help evaluate long-term performance. Additionally, integrating this approach with other renewable energy sources, such as solar or wind power, can lead to hybrid energy solutions that improve reliability and overall energy availability. These enhancements can strengthen the power generation as a supplementary energy source in sustainable smart city infrastructure.

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