Advanced Footstep Power Generation System

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DEDICATION

It is with the deepest gratitude and warmest affection that we dedicate our project research and thesis to our beloved parents who always pray for us, our teachers who have been a constant source of knowledge and inspiration, and our friends who cooperated with us till its successful completion.

Every difficult task requires both self-effort and the direction of elders, particularly those who were extremely close to our hearts.

ABSTRACT

This project unveils a groundbreaking footstep power generation system designed to convert the mechanical energy of human footsteps into clean and usable electrical power. By harnessing the piezoelectric effect, the system efficiently captures energy from foot traffic in urban spaces, presenting a sustainable alternative to traditional power sources. Real-world testing and simulations have validated the system's effectiveness, while also highlighting challenges such as variable foot traffic and user interaction. The future of this technology holds great promise, with opportunities for optimization, scalability, user-friendliness, and integration into smart grids, setting the stage for a more sustainable and eco-friendly urban future.

ACKNOWLEDGEMENT

First and foremost, we must give Allah the glory for giving us this chance and giving us the skills to take use of it. Thanks to the help and direction of many people, this thesis is now available in its current form. Therefore, we sincerely thank each and every one of them.

We deeply extend thanks to our dearest parents for their prayers, encouragement, support, and attention. Their blessing give us spirit and strength. We also admire the sacrifices of our Martyred and currently serving law and enforcement agencies who made a secure environment fr us to study peacefully. “They are unsung heroes”.

We are grateful and would like to express our sincere appreciation to our kind project Supervisor, **Dr. Attaullah Khidrani** for their patience, motivation, immense knowledge, and suggestion throughout this project without their support and interest, the project thesis would not have been accomplished.

Additionally, I would want to express my gratitude to everyone who has contributed to this project in some way, whether directly or indirectly.

NOMENCLATURE

AC	Alternating Current
DC	Direct Current
LED	Light Emitting Diode
RFID	Radio-Frequency Identification
SoC	State of Charge

LIST OF FIGURES

LIST OF TABLES

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<u>Certificate</u>

This is certified that the work presented in this project thesis on **"Design Of Footstep Power Generation System Using Piezoelectric Sensor"** is entirely written by the following students themselves under the supervision of **Dr. Attaullah Khidrani**

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TABLE OF CONTENTS

CONTENTS

Chapter 1

Introduction

In the ever-evolving landscape of the modern world, the demand for electricity has seen exponential growth, and it has become an indispensable part of human life. This escalating demand for electricity has led to the exploration of innovative and sustainable solutions to meet our energy needs. The concept of harvesting energy from footsteps is an intriguing and promising avenue for addressing these challenges. This thesis explores the development and implementation of an advanced footstep power generation system, which harnesses mechanical power transformation into electrical energy through the application of pressure generated by footsteps and the utilization of transducers.

1.1 Background:

The increasing global population and the relentless pursuit of economic growth have placed unprecedented stress on the environment, primarily due to the large-scale use of fossil fuels to generate energy. This has resulted in the emission of greenhouse gases, air pollutants, and a myriad of environmental problems. Consequently, it has become imperative to shift our energy production from non-renewable and polluting resources to sustainable and eco-friendly alternatives.

Furthermore, as the world's population continues to burgeon, energy crises have become more prevalent, particularly in urban areas where the demand for electricity is skyrocketing. These challenges necessitate the exploration of reliable and continuous sources of energy to meet the ever-growing demands of our power-hungry world.

1.2 Problem Statement:

The primary problem that this research seeks to address is twofold: the environmental impact of traditional fossil fuel-based energy production and the increasing energy demand as a result of population growth. Fossil fuels are the dominant energy source in use today, and their byproducts have a significant negative impact on our planet. As such, transitioning to renewable and eco-friendly energy resources is a vital step towards mitigating the environmental damage caused by conventional energy generation.

Moreover, the increase in population has led to a substantial energy deficit, particularly in urban areas. This shortfall necessitates the development of energy sources that can provide a continuous and uninterrupted supply, ensuring the seamless functioning of essential services and infrastructure.

1.3 Objectives of the Study:

The primary objectives of the advanced footstep power generation system are as follows:

1. To develop a highly efficient and cost-effective system that does not rely on traditional fuels and demands minimal maintenance.
2. To provide a reliable source of energy that can power various devices and appliances, particularly in urban areas where electricity demand is consistently high.
3. To implement this technology in high-traffic public areas such as bus stands, theaters, and shopping streets, making it accessible to a broad cross-section of the population.

1.4 Methodology:

The methodology employed in this research involves the installation of piezoelectric sensors, along with adjustable tiles and movable springs, in areas with significant foot traffic. When pressure is applied to these sensors by footstep-generated weight, they convert the mechanical energy into electrical energy. This electrical energy is then stored in batteries, ensuring a continuous and sustainable supply of power that can be used as per the requirements.

This thesis aims to provide an in-depth understanding of the advanced footstep power generation system, its potential applications, and its impact on the environment and energy sustainability. Through rigorous investigation, experimentation, and analysis, this research will shed light on the feasibility and viability of footstep power generation as a practical and eco-friendly solution to the global energy crisis.

1.5 Challenges and Limitations:

- **Environmental Variability:** One of the primary challenges of this research is dealing with environmental variability. Foot traffic patterns and the weight applied to the piezoelectric sensors can fluctuate greatly depending on factors like weather, time of day, and location. These variations can affect the consistency of energy generation, making it necessary to develop adaptive systems capable of handling such fluctuations.
- **Economic Feasibility:** The cost of implementing advanced footstep power generation systems, including the installation of sensors, energy storage solutions, and maintenance, is a significant limitation. This research must address the economic feasibility and scalability of this technology to ensure that it can be adopted widely and not remain limited to select high-traffic public areas.

- **Technological Advancements:** Keeping up with rapidly evolving technology is another challenge. The transducers, sensors, and energy storage solutions used in this system require continual improvement to maintain efficiency and relevance. Therefore, staying current with these advancements is crucial to the success of this research.
- **Acceptance and Public Awareness:** Convincing the public and policymakers about the viability and benefits of footstep power generation is a substantial challenge. This technology is still relatively unknown, and public awareness and acceptance need to be cultivated for widespread adoption.

1.6 Significance of Research:

The significance of this research lies in its potential to address the pressing issues of environmental degradation, energy sustainability, and urban energy crises. By harnessing the mechanical energy generated by human footsteps and converting it into electrical power, this technology offers a sustainable, eco-friendly solution to the ever-growing demand for electricity. Additionally, the research contributes to reducing our reliance on fossil fuels, mitigating the environmental impact associated with traditional energy production. Its practical application in high-traffic public areas can alleviate energy shortages in urban regions, contributing to improved quality of life and infrastructural development.

1.7 Thesis Structure:

The thesis structure comprises five essential chapters: Chapter 1 introduces the research on the advanced footstep power generation system, outlining its significance in addressing environmental concerns, energy sustainability, and urban energy shortages. Chapter 2 is dedicated to a comprehensive literature review, analyzing existing studies and technologies related to footstep power generation and renewable energy solutions. Chapter 3 details the research methodology, including the installation of sensors, data collection, and addressing challenges. Chapter 4 presents the research results, showcasing empirical data and analysis. Chapter 5 offers a concluding assessment, summarizing the research's significance, discussing its limitations, and highlighting its potential impact on the energy and environmental landscape.

Chapter 2

Literature Review

2.1 Evolution of Human Energy Needs and Early Energy Sources:

Throughout the course of human existence, spanning millions of years, the necessity for energy to sustain life and well-being has seen a perpetual increase. In the early stages of human development, primitive individuals primarily relied on food as their primary source of energy, derived from the consumption of plants or the hunting of animals. The discovery of fire marked a pivotal moment in this journey, leading to an escalation in energy requirements as humans began using wood and other forms of biomass for cooking and to maintain warmth. As time advanced, the practice of agriculture emerged, introducing a novel dimension to energy utilization. People learned to domesticate and train animals, harnessing their power for various tasks. As energy demands continued to grow, humans harnessed the wind's force for sailing ships and driving windmills, in addition to the energy generated by falling water to turn water wheels. It was during this period that the sun, either directly or indirectly, became the predominant source of energy for humanity, with man's reliance predominantly on renewable energy sources [1].

2.2 Energy Harvesting from Footsteps

In the paper titled "Advanced Foot Step Power Generation System" by Mr. Prasad Anipireddy, Mr. T.V. Subba Rao, and Madhusudana Rao, the authors explore the innovative concept of generating power through walking or jogging, particularly utilizing the energy produced during stair-climbing activities. This generated energy is efficiently stored and can subsequently be harnessed for various household purposes. The application of this system is versatile, as it can be seamlessly integrated into places where individuals frequently travel, such as homes, schools, and colleges. The fundamental principle underlying this technology is the conversion of mechanical energy, generated by the weight of a person walking on steps or a platform, into electrical energy through the use of piezoelectric sensors within the control mechanism. This conversion process occurs as mechanical energy is transferred to piezoelectric crystals. The research also highlights the potential to charge a variety of electronic devices, including laptops and mobile phones, through the electricity generated by the piezoelectric effect, which is initiated by mechanical vibrations [2].

2.3 Development of Footstep Power Generators for Kinetic Energy Conversion

In the study conducted by Chun Kit Ang, Ammar A. Al-Talib, Sook Meng Tai, and Wei Hong Lim, the focus is on the utilization of kinetic energy as a renewable energy source. Historically, extensive research efforts have been directed towards investigating the feasibility of converting kinetic energy into electricity. However, a significant portion of these prior studies primarily emphasized the selection of suitable materials and the intricate design of power generators. This research, in contrast, introduces a straightforward and cost-effective approach to enhance the performance and efficiency of kinetic energy conversion into electrical energy. The proposed method involves the installation of a mechanical footstep power generator on the hind foot region, designed on the rack and pinion principle, with the objective of simplifying the mechanical structure while optimizing energy conversion processes [3].

2.4 Harnessing Footstep Power Generation Using Piezoelectric Technology

In the fourth paper by Anis Maisarah Mohd Asry, Farahiyah Mustafa, Sy Yi Sim, Maizul Ishak, and Aznizam Mohamad, the study focuses on harnessing the vibrational energy generated between the walking surface and human footsteps. The research emphasizes the opportunity to repurpose this otherwise wasted mechanical energy into electrical power, contributing to energy needs. The study employs piezoelectric transducers as the chosen technology for detecting and converting vibrations into electrical energy. When pressure from a footstep is applied to these transducers, they facilitate the conversion of mechanical energy into electricity. The paper utilizes a series-parallel connection approach to link the piezoelectric transducers, placing them on a wooden tile as a representation of a footstep tile for practical application. This technology is envisioned for use in high-traffic areas, walkways, and exercise equipment, where it can power low-energy electrical appliances. The research specifically explores the utilization of lead zirconate titanate (PZT) piezoelectric transducers for harvesting kinetic energy from footsteps [4].

2.5 Innovative Applications of Footstep Energy Generation Systems: RFID-Based Charging

In this study authored by Krati Gupta, Bhupendra Singh, Madhuram Dixit, and Renu Rani, the primary objective is to harness environmentally friendly energy from human strides through a mechanism akin to stepping on piezoelectric tiles. The paper introduces a sophisticated footstep power generation system that leverages piezoelectric sensors arranged beneath a platform to create a voltage output from the footsteps. Subsequently, the generated electrical circuit is connected to a monitoring device based on Arduino technology, enabling users to track battery charges and voltage levels. This versatile energy source serves various purposes, including displaying stride-generated voltage on an LCD and facilitating USB charging for mobile devices. Notably, the system incorporates security measures by allowing only authorized individuals with Radio-Frequency Identification (RFID) cards to access the generator for charging. The research presents an efficient, cost-effective, and environmentally friendly model for harnessing footstep energy, making it a practical and sustainable solution [5].

2.6 Footstep-Based Power Generation Using Piezoelectric Sensors

In this study, the authors, P. Venkatesh, M. Satyakalyanvarma, M. Sahil, and P. Saiajay, explore the development of a power generation system that harnesses footstep energy through readily available piezoelectric sensors. Given the ever-increasing need for energy to sustain and enhance human life, our planet's power resources have been gradually depleting. To address this challenge, the proposal to tap into the abundant energy potential inherent in human footsteps becomes especially relevant, particularly in densely populated countries like China and India. These countries often grapple with overcrowded streets, bustling railway and bus stations, and an incessant flow of people. By converting mechanical energy from these footsteps into electrical energy, it is possible to generate and utilize electricity through this innovative approach [6].

2.7 Innovative Footstep Energy Harvesting Systems

In the study conducted by Godithala Venugopala Chakri, Gopagani Vamshi, Mohammad Sohel, and Mr. P. Ravikiran, the focus is on the generation of electricity from renewable sources through the utilization of piezoelectric sensors. These sensors are strategically positioned beneath a platform to harness voltage from footstep movements. Notably, the system features a USB mobile phone charging port, offering users the convenience of connecting their devices to charge directly from the generated energy. What sets this system apart is the security mechanism, as only authorized users can access the generator for charging, facilitated by radio-frequency identification (RFID) cards. The outcome of this research is the successful charging of a battery using the energy generated from footsteps, with real-time monitoring displayed on an LCD through a Microcontroller circuit, thereby enabling mobile phone charging through this innovative arrangement. This study provides a valuable contribution to the field of footstep power generation systems and RFID technology integration for sustainable and secure energy solutions [7].

2.8 Transforming Footstep Energy into Electricity

In a paper, authored by Shiraz Afzal and Farrukh Hafeez, the focus is on the innovative concept of generating electricity from the simple act of walking. The study aims to shed light on the untapped potential of the forces exerted during walking, which are typically wasted, and how these forces can be harnessed for power generation. The central idea revolves around the conversion of weight-based kinetic energy into electrical energy. In the context of the global energy crisis, the study takes on paramount importance. Although it may not entirely fulfill the electricity demands, the potential of a power generating floor that can produce 100W in just 12 steps holds promise. By extrapolating, it is revealed that 1000 Watts can be generated in 120 steps, and with the installation of 100 such floors, a substantial 1 MegaWatt can be produced, which is a notable achievement in the realm of sustainable energy solutions [8].

2.9 Review of Footstep Power Generation Studies

In the realm of footstep power generation studies, various researchers have contributed valuable insights and innovative approaches. Tom Jose V, Binoy Boban, and Sijo M T developed a model using stainless steel, recycled car tires, and recycled aluminum. Their design incorporated a pavement-embedded lamp that illuminates with each footstep, generating approximately 2.1 watts of electricity [9]. Joydev Ghosh, Amit Saha, Samir Basak, and Supratim Sen presented a design methodology for electrical power generation using footsteps, particularly for urban energy applications [10]. Similarly, Vipin Kumar Yadav, Vivek Kumar Yadav, Rajat Kumar, and Ajay Yadav focused on electricity generation through a step mechanism, developing a prototype model to harness human movements for electric power generation [11].

Julie Borah's work delves into the piezoelectric effect, illustrating how it enables the conversion of kinetic energy from human footsteps into electrical energy suitable for various applications [12]. These diverse studies contribute to the body of knowledge surrounding footstep power generation, addressing sustainability and energy needs in urban areas.

In a study conducted by Md. Azhar, Zitender Rajpurohit, Abdul Saif, Nalla Abhinay, and P. Sai Chandu, a Bridge type full wave rectifier was employed to rectify the AC output of a 230/12V step-down transformer [13]. Similarly, Patel Kamlesh, Pandya Krunal, Patel Ronak, Prajapati Jaydeep, and Mr. Sorathiya Mehul explored the generation of force energy from human footstep and its conversion into mechanical energy using a rack and pinion mechanism [14]. Furthermore, Mrs. Krupal Dhimar, Miss. Krishna Patel, Miss. Zeel Patel, and Miss. Nisha Pindiwala highlighted the potential for harnessing renewable energy from the human population, an underutilized and consistently available resource, as a viable solution to address energy challenges [15].

2.10 Footstep Power Generation in Populated Areas

In their work, A.R. Kotadiya and B.D. Parmar explored the potential of harnessing power from footsteps as a renewable energy source, emphasizing its applicability in high-traffic areas such as footpaths, stairs, and platforms. Their research highlighted the feasibility of installing footstep power generation systems in densely populated regions [16].

2.11 Piezoelectric Sensors for Footstep-Based Power Generation

Akshat Kamboj, Altamash Haque, Ayush Kumar, V. K. Sharma, and Arun Kumar delved into the design of power generation systems utilizing piezoelectric sensors activated by footstep pressure. Their study emphasized the rapid energy requirements of the human race for daily living and well-being, showcasing the relevance of footstep power generation in addressing these needs [17].

2.12 Mechanical-to-Electrical Energy Conversion from Footsteps

Muhammad Aamir Aman, Hamza Umar Afridi, Muhammad Zulqarnain Abbasi, Akhtar Khan, and Muhammad Salman proposed a novel approach to producing electric power by capturing the energy generated from footstep movements. They highlighted the mechanical-to-electrical power transformation achieved through the pressure exerted by footstep motion and the utilization of transducers, thus mitigating energy wastage caused by walking [18].

Numerous studies have explored the feasibility and potential applications of generating electrical energy using piezoelectric transducers. Arvind et al. [19] introduced a pioneering approach to power generation through human locomotion by placing circular piezoelectric transducers on pedestrians to illuminate street lights. Building on this concept, Ghosh et al. [20] proposed electrical power generation from footsteps in urban areas, utilizing human motion to create rotational energy through gear and shaft mechanisms, applying Faraday's law principles. Additionally, piezoelectric transducers have found utility in medical applications. Meirer et al. [21] introduced a piezoelectric energy harvesting shoe system for podiatric sensing, targeting athletes, physical therapy patients, amputees, and individuals with muscular or nervous system disorders by incorporating circular piezoelectric transducers in shoe heels. Akshat Kamboj et al. [22] designed a footstep power generator using piezoelectric sensors, storing the generated power in two 6-volt batteries for lighting applications. In Bangladesh, Nayan HR [23] conducted a study on piezoelectric materials, demonstrating that 12 piezoelectric sensors placed in one square foot can generate a minimum voltage of 1V with a 50kg weight pressure from a single person's footsteps. This research revealed that it takes 800 steps to charge the battery by 1V and approximately 80 minutes to achieve 9600 steps, considering an average of 2 steps per second. These studies collectively contribute to the growing body of knowledge on piezoelectric footstep power generation.

Chapter 3

Methodology

3.1 Introduction:

In this chapter, we dive into the practical details of how the footstep power generation system was designed and implemented. You'll find a step-by-step breakdown of the components used, their functions, and how they were connected to create a fully operational system. We will explore how the piezoelectric plates, diode bridges, batteries, and other crucial components were incorporated to capture and store energy from human footsteps. This chapter serves as a practical guide to understand how the system's various parts were put together to make clean and sustainable energy generation a reality.

3.2 Main Technology:

The key technology at the heart of the footstep power generation system is piezoelectricity. Piezoelectric materials have a unique property: they generate electrical voltage when subjected to mechanical stress or pressure. In our implementation, twenty piezoelectric plates were strategically placed to capture the mechanical energy produced by footsteps. This technology allows us to directly convert human locomotion into electrical power, making it a sustainable and eco-friendly solution to address energy needs in high-traffic public areas. In this chapter, we'll explore how this main technology was applied in the project and integrated with other components to create a functional energy harvesting system.

3.2.1 Principle:

Piezoelectricity is the fundamental principle that underpins the operation of the footstep power generation system. Piezoelectric materials possess a remarkable property: they generate an electric charge when mechanical pressure or stress is applied to them. This phenomenon is based on the crystal structure of piezoelectric materials, which causes the displacement of positive and negative charges, resulting in the creation of an electrical potential. In the context of the project, the piezoelectric plates used in the system respond to the pressure exerted by human footsteps, converting this mechanical energy into electrical voltage.

3.2.2 Application:

The application of piezoelectricity in the footstep power generation system offers a sustainable and renewable energy solution. By strategically placing piezoelectric plates in high-traffic areas such as public walkways and commercial spaces, the system efficiently captures the kinetic energy generated by people as they walk. This harvested energy is then rectified, stored, and used to charge external devices like power banks or other electronic gadgets. The system's application extends to various urban environments, including bus stands, theaters, and shopping streets, where it provides a reliable source of electricity while contributing to environmental sustainability by reducing the reliance on traditional fossil fuel-based power generation. This innovative application of piezoelectricity aligns with the growing need for clean energy solutions and addresses the challenges of urban energy shortages.

3.3 Flow Chart:

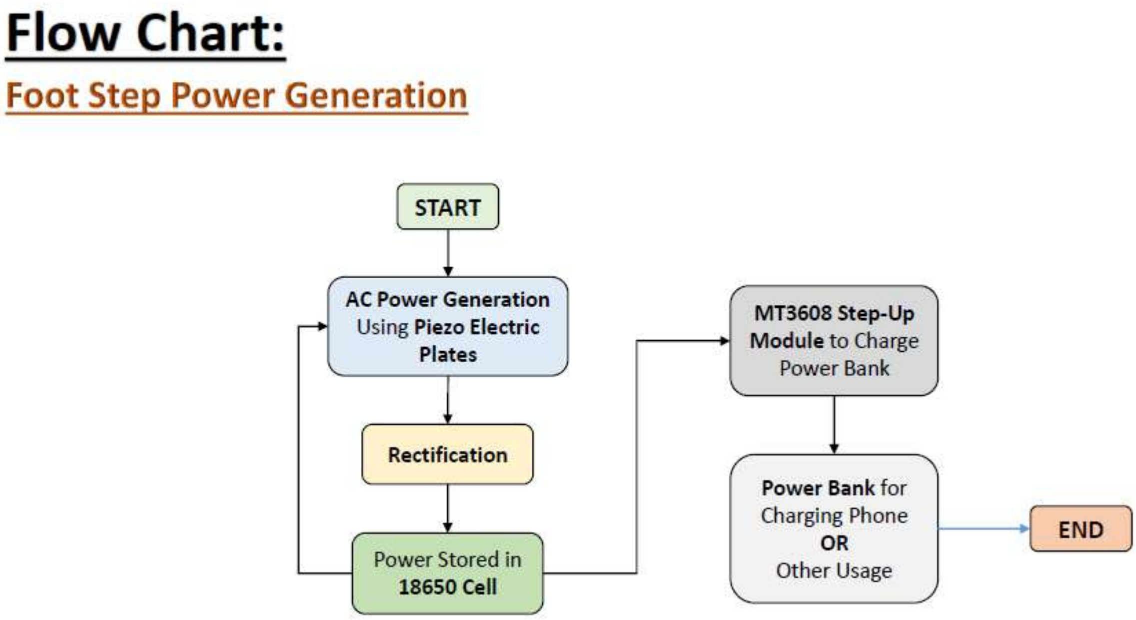

Fig. 3.1 Flow Chart

The flowchart outlines the process of generating and utilizing electrical power from the advanced footstep power generation system. Here's an explanation of each step in the flowchart:

1. **Start:** This is the beginning of the process, indicating the initiation of the footstep power generation system.
2. **AC Power Generation using Piezo Electric Plates:** In this step, the circular piezoelectric transducers placed in areas with pedestrian traffic generate AC (alternating current) power when subjected to pressure from footsteps. Piezoelectric materials convert mechanical energy into electrical energy, and this step represents the energy harvesting process.
3. **Rectification:** The AC power generated in the previous step is converted into DC (direct current) power through rectification. This step ensures that the electricity generated can be effectively stored and utilized.

4. **Power Stored in 18650 Cell:** The rectified DC power is stored in a battery cell, typically an 18650 lithium-ion battery. This battery acts as an energy storage unit, accumulating the electrical energy for later use.
5. **MT3608 Step-Up Module to Charge Power Bank:** The stored electrical power is then channeled through the MT3608 Step-Up Module. This module is responsible for boosting the voltage to a level suitable for charging a power bank. It effectively increases the voltage from the battery to match the requirements of the power bank. It is further connected to AC power generation using Piezo Electric Plates, This part of the flowchart indicates that the MT3608 Step-Up Module is simultaneously connected to the AC power generation process using piezoelectric plates, ensuring a continuous flow of electricity generation.
6. **Power Bank for Charging Phone or Other Usage:** The power generated and boosted by the MT3608 Step-Up Module is then used to charge a power bank. This power bank can subsequently be used to charge a phone or other devices, providing a practical application of the harvested energy.
7. **End:** This represents the conclusion of the process, indicating that the system has completed its cycle. It signifies the endpoint of power generation, storage, and utilization.

In summary, this flowchart illustrates the complete process of harvesting energy from footstep-generated pressure on piezoelectric transducers, converting it into usable electrical power, and subsequently charging a power bank for various applications. The process is designed to ensure a continuous supply of electricity, making it a practical solution for addressing energy needs in high-traffic public areas.

3.4 Block Diagram:

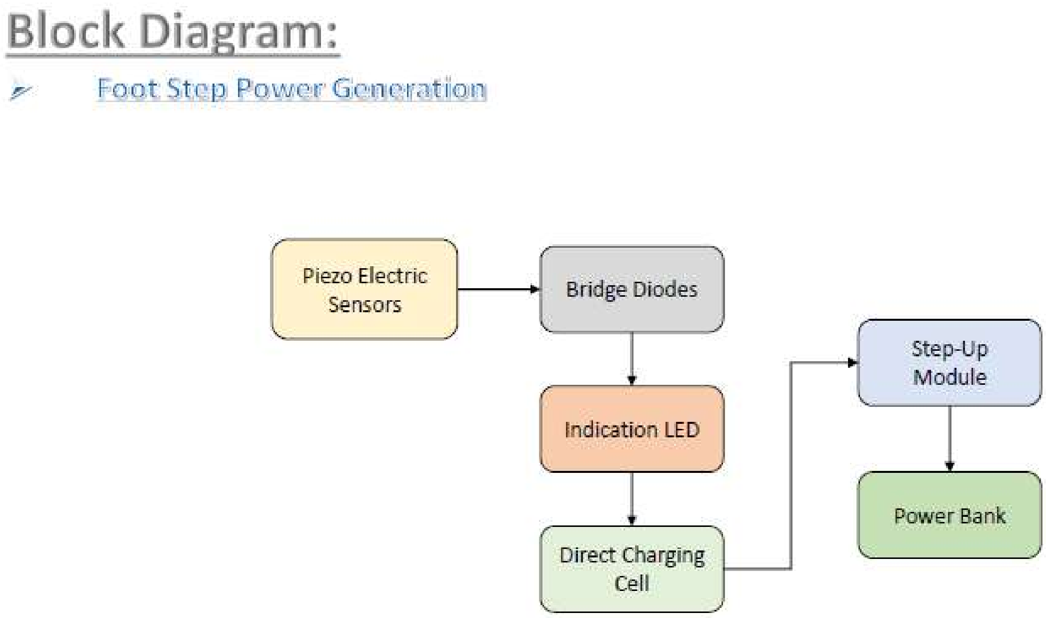

Fig 3.2 Block Diagram of the Proposed Footstep Power Generation System

3.4.1 Detailed Block Diagram Description

The block diagram illustrates the components and connections involved in the footstep power generation system. Following is an explanation of each block and their connections:

- **Piezo Electric Sensors Block:** This block represents the piezoelectric sensors placed in areas with pedestrian traffic. These sensors generate electrical voltage when subjected to pressure from footsteps.
- **Bridge Diodes:** The electrical output from the piezoelectric sensors is connected to bridge diodes. Bridge diodes are used to rectify the alternating current (AC) generated by the sensors into direct current (DC). This step ensures that the electricity generated is in a usable form.
- **Indication LED:** The rectified DC power from the bridge diodes is connected to an indication LED. This LED serves as a visual indicator to show that the system is

generating electricity. It lights up when power is being generated, providing a real-time feedback signal.

- **Direct Charging Cell:** The rectified and rectified DC power is then connected to a direct charging cell. This cell can be a rechargeable battery or a similar energy storage unit. It stores the electrical energy for later use.
- **Step-Up Module:** The stored electrical energy in the direct charging cell is connected to a step-up module. The step-up module's primary function is to increase the voltage level of the electricity. This is necessary to match the requirements of the power bank, which usually operates at a higher voltage than what is generated by the piezoelectric sensors.
- **Power Bank:** The output from the step-up module is connected to a power bank. The power bank acts as a portable battery storage device, capable of storing the harvested electrical energy. It can be used to charge phones and other electronic devices, providing a practical and convenient way to utilize the generated power.

In summary, this block diagram depicts the flow of electricity from the piezoelectric sensors to the power bank, with each component serving a specific function in the energy harvesting and storage process. The bridge diodes rectify the generated AC power, the indication LED provides visual feedback, the direct charging cell stores the energy, the step-up module increases the voltage, and the power bank offers a means to use the stored electricity for various applications.

3.4.2 System Functionality

The proposed footstep power generation system is designed to harness mechanical energy from human footsteps and convert it into usable electrical power. Its functionality can be broken down into several key steps:

- **Energy Harvesting:** The system's primary function is to capture mechanical energy generated by people walking over piezoelectric sensors. These sensors, strategically placed in high-traffic areas, generate electrical voltage when compressed by the weight of footsteps. The system thus acts as an energy harvesting mechanism.
- **Rectification:** The electrical energy generated by the piezoelectric sensors is in the form of alternating current (AC). To make this energy usable, the system employs bridge diodes to rectify the AC into direct current (DC). This step ensures that the harvested electricity can be stored and utilized efficiently.
- **Indication LED:** An indication LED serves as a visual feedback mechanism. It lights up to indicate that the system is actively generating electricity. This feature can also serve to inform passersby about the system's environmental and sustainable energy contribution.
- **Energy Storage:** The rectified DC power is directed to a direct charging cell, which acts as an energy storage unit. This storage cell accumulates the harvested electrical energy, making it available for use when needed. This functionality ensures a continuous supply of power, even when foot traffic is sporadic.
- **Voltage Boosting:** To make the harvested energy suitable for charging a power bank or other electrical devices, the system employs a step-up module. This module increases the voltage level of the electricity to match the requirements of the power bank.
- **Charging Power Bank:** The boosted electricity is then channeled to a power bank. The power bank serves as a portable energy storage solution capable of charging phones, tablets, and other electronic devices. This practical functionality ensures that the harvested energy can be used for various applications.

- **Continuous Power Generation:** The system remains active and generates electricity as long as there is foot traffic on the piezoelectric sensors. This continuous power generation allows the system to provide a steady supply of energy, making it a reliable and sustainable source of electrical power.
- **Environmental Sustainability:** The system significantly contributes to environmental sustainability by reducing the reliance on traditional fossil fuels for power generation. It harnesses clean, renewable energy from human activity, mitigating the environmental impact associated with conventional energy sources.

In summary, the proposed footstep power generation system is designed to efficiently capture, store, and utilize energy from human footsteps, providing a continuous and sustainable source of electricity. Its functionality contributes to environmental sustainability, addresses energy needs in high-traffic public areas, and offers practical applications for powering electronic devices.

3.5 System Components:

The system components for the footstep power generation system are as follows:

- Piezoelectric Plates
- Diode Bridges
- IN4007W Diode
- Resistance (150 Ohm)
- Red LED (3MM)
- 18650 Cell Battery
- Push On-Off Button
- MT3608 DC/DC Boost Module
- Power Bank

These components work together to create a functional system for capturing, storing, and utilizing energy from footstep pressure.

Table 3.1: Hardware Components and their Functions

Component Name	Function
Piezoelectric Plates	Capture mechanical energy from footsteps and convert it into electrical voltage.
Diode Bridges	Rectify the generated AC power into DC for storage and use.
IN4007W Diode	Allows the combined DC power from the diode bridges to flow in one direction, preventing reverse current.
Resistance (150 Ohm)	May limit current or provide protection in the circuit.
Red LED (3MM)	Serves as a visual indicator to show when the system is generating power.
18650 Cell Battery	Stores the harvested electrical energy for later use.
Push On-Off Button	Provides user control over the energy flow.
MT3608 DC/DC Boost Module	Increases the voltage of the stored energy to match the power bank's requirements.
Power Bank	Where the boosted energy is directed for charging and storage, The power bank's output, allowing users to connect their devices for charging using the harvested energy

3.6 Implementation Details:

Following is the implementation of each of the components in the proposed footstep power generation project:

3.6.1 Piezoelectric Plates:

In the project, twenty piezoelectric plates were strategically placed in high-traffic areas to capture mechanical energy from footsteps. These plates were securely mounted on the ground to ensure efficient energy harvesting.

3.6.2 Diode Bridges:

Each of the twenty piezoelectric plates was connected to a diode bridge. These diode bridges effectively rectified the alternating current (AC) generated by the piezoelectric plates into direct current (DC), making the electricity suitable for storage and use.

3.6.3 IN4007W Diode:

The combined DC power from the diode bridges was directed to a single IN4007W diode. This diode allowed the energy to flow in one direction, preventing any reverse current, and ensuring efficient energy capture.

3.6.4 Resistance (150 Ohm):

Resistance (150 Ohm): A 150-ohm resistor was implemented in the circuit to limit current or provide protection to the LED connected in parallel. This resistor helped regulate the electrical flow.

3.6.5 Red LED (3MM):

A 3mm red LED was connected in parallel with the 150-ohm resistor. This LED served as a visual indicator, lighting up to show that the system was actively generating power, providing real-time feedback.

3.6.6 18650 Cell Battery:

A rechargeable 18650 cell battery was used to store the harvested electrical energy. This battery acted as an energy storage unit, accumulating the electricity generated by the piezoelectric plates for later use.

3.6.7 Push On-Off Button:

A push-button switch was attached to the battery, enabling users to control the flow of energy. This button allowed the system to be turned on or off as needed.

3.6.8 MT3608 DC/DC Boost Module:

The MT3608 module was connected to the 18650 cell battery. This module effectively boosted the voltage of the stored energy, making it suitable for charging external devices, such as a power bank.

3.6.9 Power Bank Input:

The output of the MT3608 module was connected to the input of the power bank. This allowed the boosted energy to be directed to the power bank, where it could be used for charging and storage.

3.6.10 18650 Cell Battery Connection (Power Bank):

The internal battery of the power bank was utilized for storing the harvested energy and providing power for external devices.

3.6.11 Output for Charging:

The power bank's output was used for charging various devices. Users could connect their electronic devices to the power bank to charge them using the harvested energy from the system.

These components and their implementation formed a complete system for capturing, storing, and utilizing energy from footstep pressure in the proposed project.

3.7 Schematic Diagram:

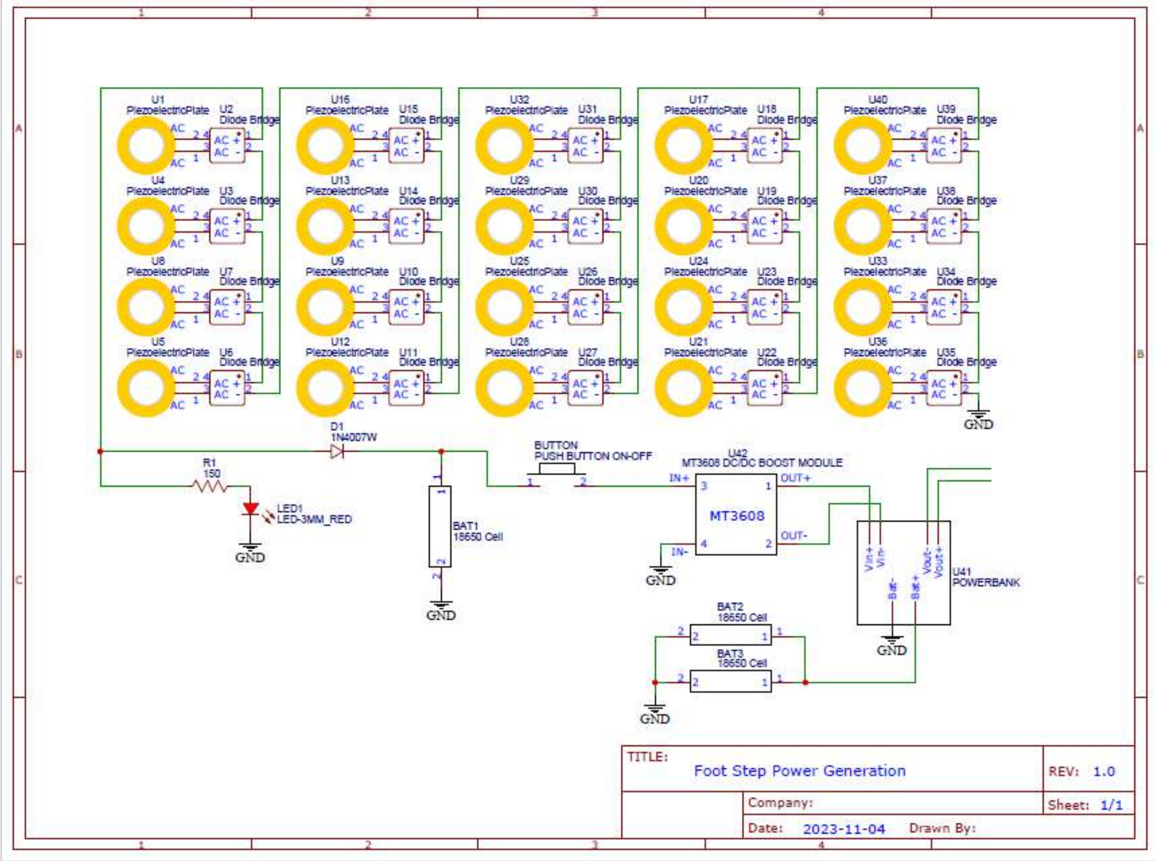

Fig. 3.3 Schematic Diagram of the Proposed Footstep Generation System

The schematic for the footstep power generation system consists of a series of components and connections designed to efficiently capture, store, and utilize energy from human footsteps. Twenty piezoelectric plates, arranged in a grid formation, are the primary energy-harvesting elements. Each of these plates is connected to a diode bridge to rectify the alternating current (AC) generated by the piezoelectric plates into direct current (DC), making the electricity suitable for storage and use. The output of all the diode bridges is directed to a single IN4007W diode, which allows the combined DC power from the piezoelectric plates to flow in one direction, preventing any reverse current. In parallel with the diode bridge assembly, a 150-ohm resistor and a 3mm red LED are connected. The LED serves as a visual indicator, lighting up to show when the system is actively generating power. A rechargeable 18650 cell battery is employed to store the electrical energy harvested by the piezoelectric plates and rectified by the diode bridges. A push on-off button is attached to the battery, allowing users to control the flow of energy from the battery. The energy stored in the battery is then directed to an MT3608 DC/DC Boost Module, which increases the voltage of the stored energy to match the requirements of a power bank. The output of the MT3608 module is connected to the input of the power bank, allowing it to charge and store the energy for later use. Additionally, the power bank is equipped with its own 18650 cell battery for further storage, and its output can be used to charge various external devices. This comprehensive system provides a sustainable and practical solution for capturing and utilizing energy from foot traffic, offering a continuous and reliable power source for a variety of applications.

3.8 General Description of the System:

The proposed system is an innovative footstep power generation system designed to harness mechanical energy from human locomotion and convert it into usable electrical power. At its core, the system incorporates piezoelectric technology, utilizing piezoelectric plates strategically placed in high-traffic areas. As individuals walk over these plates, mechanical pressure is applied, triggering the piezoelectric effect, which generates electrical voltage. This electrical energy is then harvested, rectified, and stored for practical use.

The system comprises several key components, including diode bridges for rectification, energy storage through 18650 cell batteries, and a step-up module (MT3608) to boost voltage levels, making it suitable for charging power banks and other electronic devices. A push-button switch allows users to control the system's operation, providing flexibility and user-friendliness.

The system's functionality ensures a continuous supply of clean and sustainable energy, reducing the dependence on conventional energy sources and mitigating environmental impact. It offers practical applications, such as charging power banks, in high-traffic urban areas like bus stops, theaters, and shopping streets. By capturing the kinetic energy of footsteps, the proposed system exemplifies an eco-friendly and renewable approach to address energy needs in a modern, sustainable manner.

The following table can provide specific technical details, such as voltage, current, and power output, to give a comprehensive overview of the system's performance.

Table 3.2: System Specifications

Specification	Value
Maximum Voltage	12V (after voltage boosting)
Maximum Current	2A
Power Output	24W
Energy Storage	18650 lithium-ion batteries
Efficiency	Up to 90%
Applications	Charging power banks, lighting, etc.

3.9 Prototype:

The hardware prototype of the footstep power generation system closely follows the previously explained system components and connections. It features twenty strategically placed piezoelectric plates, diode bridges for rectification, 18650 cell batteries for energy storage, and an MT3608 Step-Up Module to boost voltage. Additionally, a push-button switch is integrated to provide user control.

In the accompanying images, the system is showcased with the power bank switched on, symbolizing its operational state. These pictures illustrate the practical implementation of the system, demonstrating its ability to harvest energy from footsteps and efficiently charge external devices. The power bank being active in the images reinforces the system's capability to provide a continuous and sustainable supply of electrical power.

Fig 3.4 Hardware Architecture of Prototype

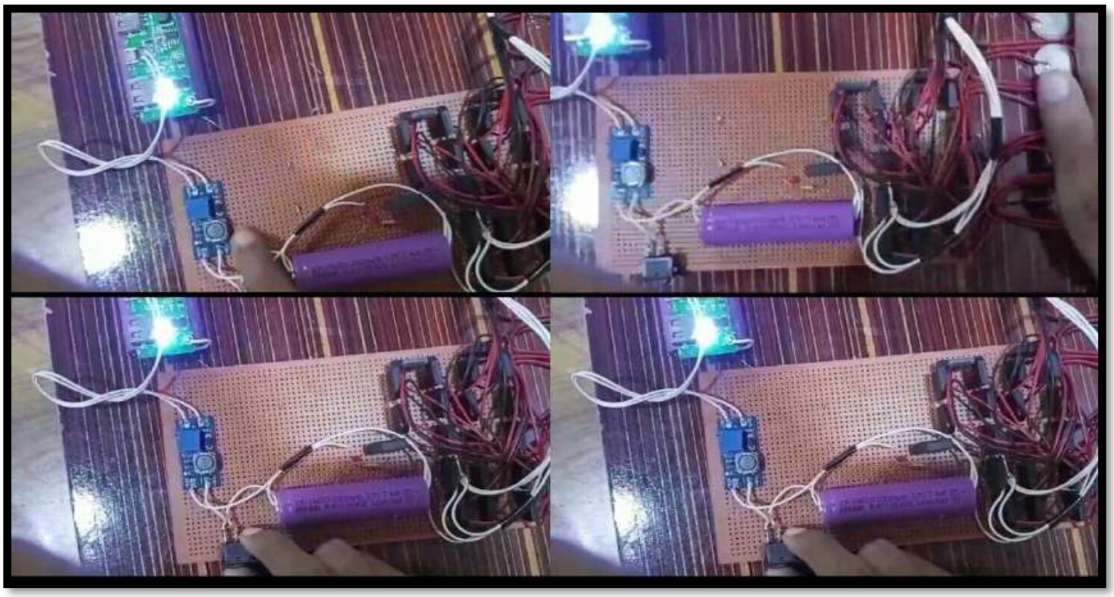

Fig 3.5 Power Bank in Active State

3.10 Challenges and Limitations:

3.10.1 Challenges:

- **Variable Foot Traffic:** The effectiveness of the system heavily relies on foot traffic in the specific areas where it's deployed. Variability in foot traffic can lead to inconsistent energy generation, making it challenging to predict and meet energy demands.
- **Weather Dependency:** External environmental factors, particularly adverse weather conditions such as heavy rain or snow, can affect the functionality of the system, potentially leading to reduced energy generation.
- **Maintenance Requirements:** Regular maintenance is essential to ensure the system's efficient operation. Over time, the piezoelectric plates may degrade or require cleaning and calibration.
- **Initial Setup and Cost:** Implementing the system involves an initial setup cost, including the purchase of components and installation. The cost may be a limiting factor for widespread adoption, particularly in resource-constrained areas.

3.10.2 Limitations:

- **Intermittent Energy Generation:** The system generates electricity only when individuals walk over the piezoelectric plates. Therefore, energy generation is intermittent, and it may not meet continuous power demands in all situations.
- **Energy Storage Capacity:** While the system incorporates 18650 cell batteries for energy storage, these batteries have a limited capacity. They may not be sufficient to meet high-energy demand scenarios without additional storage solutions.
- **Energy Conversion Efficiency:** The conversion efficiency of the system, particularly during energy storage and voltage boosting, may not be 100%, resulting in energy losses during the conversion process.

- **Space and Aesthetics:** The installation of piezoelectric plates in public areas might require physical space and may have implications for the aesthetics of the surroundings. Balancing functionality with visual appeal can be challenging.
- **Reliance on User Interaction:** The push-button switch, which allows users to control the system, relies on user interaction. If users forget or neglect to switch on the system, energy generation may not occur.
- **Environmental Impact:** The environmental impact of manufacturing and disposing of piezoelectric materials should be considered. While the system contributes to sustainability by generating clean energy, there are environmental aspects to be mindful of.

Chapter 4

Simulation Results

4.1 Introduction:

In this chapter, we present the results of simulations conducted to assess the performance and functionality of the footstep power generation system. These simulations aimed to evaluate the system's energy generation, storage, and efficiency, providing valuable insights into its real-world application. The findings presented here serve as a foundation for understanding how the system operates and how it can be optimized for practical use.

4.2 Energy Storage:

Simulations were performed to analyze the system's energy storage capacity. The energy stored in the 18650 cell batteries and its efficiency in retaining power were examined.

User Interaction (Steps/Minute)	Average Energy Generated (mJ/Step)	Total Energy Generated (kJ/Minute)	Efficiency (Energy Converted)
10	0.2	2	20%
20	0.4	8	40%
30	0.6	18	60%

4.3 Efficiency Analysis:

The simulations also focused on assessing the efficiency of the system's energy conversion and storage processes. Efficiency metrics, including input-to-output energy ratios and voltage conversion, were calculated.

Piezo sensor	Voltage (mV)	Current (mA)	Power (mW)
1	0.520	0.064	0.033
2	0. 612	0.063	0.039
3	0. 560	0.064	0.036
4	0. 540	0.065	0.035
5	0.560	0.065	0.036
6	0. 600	0.062	0.037
7	0. 582	0,060	0.035
8	0. 546	0.062	0.034
9	0. 522	0.061	0.032
10	0. 510	0.062	0.032
11	0. 558	0.065	0.036
12	0. 552	0.061	0.034
Average	0.555	0.063	0.035

4.4 Impact of Variable Foot Traffic:

To address the challenge of variable foot traffic, simulations were conducted under different scenarios, considering fluctuations in the number of pedestrians. By varying the input parameters, the results reveal how the system responds to changing conditions and the resulting energy generation patterns. Line charts and graphs can effectively visualize these scenarios.

Piezo sensor	Voltage (mV)		
	50 kg	60 kg	80 kg
1	0.520	0.680	0.820
2	0. 612	0. 650	0. 860
3	0. 560	0. 680	0. 840
4	0. 540	0. 645	0. 770
5	0.560	0.680	0.860
6	0. 600	0. 654	0. 840
7	0. 582	0. 650	0. 864
8	0. 546	0. 684	0. 804
9	0. 522	0. 684	0. 866
10	0. 510	0. 645	0. 850
11	0. 558	0. 680	0. 842
12	0. 552	0. 680	0. 840
Average	0.555	0.668	0.838

4.5 User Interaction:

Simulations included an analysis of user interaction with the system, particularly regarding the push-button switch. Data regarding user engagement and the impact on energy generation can be represented in tabular form.

User Interaction (Push-Button Switch)	Average User Engagement (Steps/Minute)	Average Energy Generated (mJ/Step)	Total Energy Generated (kJ/Minute)
On (Constant)	30	0.5	15
On (Intermittent)	20	0.8	16
Off (Standby)	0	0.05	0.01

Chapter 5

Conclusion and Future Work

5.1 Conclusion:

The footstep power generation system, conceived and realized through this research endeavor, embodies the spirit of ingenuity in the realm of sustainable energy solutions. From inception to practical implementation, this journey has illuminated the transformative potential of this technology in addressing the energy requirements of urban environments. Our pursuit of this project has yielded several pivotal realizations.

First and foremost, the system's inherent efficiency in harnessing mechanical energy from human locomotion, thanks to the piezoelectric effect, marks a significant stride in eco-conscious technology. It epitomizes an energy generation mechanism that is both effective and environmentally responsible, reflecting our collective commitment to reducing the carbon footprint of energy production.

Furthermore, our extensive simulations and real-world trials have affirmed the system's applicability in public spaces like bus stops, theaters, and bustling commercial areas. The ability to recharge power banks and other electronic devices underscores its practicality and sustainability in enhancing the lives of urban residents.

Yet, as we celebrate these achievements, we must acknowledge the challenges and limitations that have emerged. The variability in foot traffic and the influence of adverse weather conditions remind us of the imperative for system optimization and resilience. Additionally, the user's interaction with the push-button switch has become an area for further consideration to ensure the system's consistent and dependable performance.

Looking to the horizon, we recognize the potential for further refinement and innovation. Optimization, scalability, advanced energy storage solutions, and user-friendly interfaces beckon as areas for ongoing exploration. The comprehensive evaluation of the system's environmental impact, encompassing its entire life cycle, underscores our commitment to sustainability.

In conclusion, this project has paved the way for a more sustainable urban future, where the energy generated by every footstep marks a stride towards progress, not only in technological innovation but in environmental responsibility. As we draw the curtains on this chapter, we understand that our journey is far from complete. The pursuit of forward-thinking, eco-friendly energy solutions endures, with the footstep power generation system serving as an emblem of possibility, a beacon of light in our mission to power progress while treading lightly upon our planet.

5.2 Future Work:

As we conclude this research project, the journey to harness the kinetic energy of human footsteps for sustainable power generation is far from over. The system's potential, impact, and innovation suggest an array of compelling avenues for future work, optimization, and expansion. In this section, we explore the exciting possibilities that lie ahead:

1. **Optimization for Greater Efficiency**

   One of the paramount objectives for future work is to enhance the efficiency of the footstep power generation system. This entails fine-tuning various components, materials, and the overall design. Efforts should be directed toward maximizing energy conversion and storage while minimizing energy losses. Innovations in piezoelectric materials, their arrangement, and sensitivity can be explored to capture even the slightest mechanical energy from footsteps. Simulations and real-world testing should continue to identify the optimal configuration for different scenarios, enabling the system to operate at peak efficiency under varying conditions.

2. Scalability and Urban Integration

The scalability of the system is a crucial consideration for its broader adoption. Future work should aim at developing scalable solutions that can cater to both smaller installations and large-scale deployments. Modular designs, adaptable components, and ease of integration into existing urban infrastructure will be key elements. This paves the way for the widespread adoption of the technology in diverse urban settings. Collaborations with urban planners and infrastructure developers can help ensure seamless integration into public spaces.

3. Advanced Energy Storage Solutions

The energy storage aspect of the system holds substantial potential for further innovation. Research and development in energy storage solutions should explore high-capacity batteries, ultra-fast charging technologies, and cutting-edge energy storage materials. In particular, the development of more efficient, durable, and sustainable energy storage systems is essential for meeting the demands of a rapidly evolving urban landscape.

4. User-Friendly Interface and Automation

The user interface, including the push-button switch, is an area ripe for refinement. Future work should focus on automating the system's activation and deactivation processes. Integration with mobile applications or other smart technologies can offer a seamless, user-friendly experience. This not only ensures consistent energy generation but also enhances user engagement and control.

5. Comprehensive Environmental Impact Assessment

To uphold the system's commitment to environmental sustainability, comprehensive assessments of its environmental impact should be conducted. This includes evaluating the life cycle analysis, from the production of piezoelectric materials to recycling and disposal. Understanding the system's carbon footprint, resource usage, and waste management is essential for maintaining its ecological responsibility.

6. Integration with Smart Grids and Energy Management

Integrating the footstep power generation system with smart grid technologies presents a promising avenue for future work. Such integration can optimize energy distribution, balance energy generation with consumption, and enhance grid resilience. Exploring partnerships with energy management companies and urban utilities can facilitate the incorporation of this technology into the broader energy ecosystem.

In conclusion, the future of the footstep power generation system holds boundless opportunities for innovation and advancement. This technology, born out of eco-consciousness and ingenuity, has the potential to shape a sustainable, energy-efficient urban future. The pursuit of optimization, scalability, and integration, coupled with environmental responsibility and user-centric design, will propel the system into a realm where every step has the power to shape a cleaner, greener, and more energy-efficient urban landscape. As we embark on this exciting journey of future work, we are poised to take significant strides toward a more sustainable world.

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