Power Generation & Storage System Using Piezoelectric Sensor

Mr. M.Sreenivasulu Reddy[1], S. HemaLatha[2], T.Gayathri[3], U.Rajeswari[4], S.Jaffer Sadiq[5]
Assistant Professor[1], UG Student[2, 3, 4, 5], Department of Electronics & Communication Engineering,
Sai Rajeswari Institute of Technology, Proddatur, Andra Pradesh,516360.
sreenivasulu.madrasu@gmail.com[1],sanivarapuhemalatha52@gmail.com[2],
gayyi2004@gmail.com[3],sumanthreddy2757@gmail.com[4],shaiksadiq7684@gmail.com[5].

ABSTRACT

The increasing global demand for sustainable and renewable energy sources has led to the exploration of innovative energy harvesting techniques[1] . This paper presents a Footstep Power Generation System utilizing piezoelectric transducers to convert mechanical energy from human footsteps into electrical energy[2].The proposed system consists of an array of piezoelectric sensors embedded in a footstep platform, a unidirectional current controller, an AC ripple filter, a rechargeable battery, and an inverter for energy storage and utilization. When pedestrians walk over the platform, the applied pressure induces electrical charge generation through the piezoelectric effect[6] . The generated energy is conditioned, stored, and utilized to power low-energy electrical appliances such as streetlights, public utilities, and smart city infrastructure[3].

KEYWORDS:*Piezoelectrictransducers,energy harvesting, footstep power generation, renewable energy, sustainable power.*

INTRODUCTION

With the increasing global demand for sustainable and renewable energy sources, researchers are exploring innovative solutions to harness energy from unconventional sources. One such promising approach is footstep energy harvesting, which utilizes the mechanical pressure exerted by human footsteps to generate electrical energy. The proposed Footstep Power Generation System leverages piezoelectric transducers to convert mechanical stress into electrical charge, providing an eco-friendly and cost-effective solution for energy generation in high-footfall areas.

Piezoelectric materials possess the unique ability to generate an electric charge when subjected to mechanical stress. By embedding an array of piezoelectric sensors in a footstep platform, the system can efficiently harvest energy from pedestrian movement.

The generated energy is then processed through a unidirectional current controller and an AC ripple filter before being stored in a rechargeable battery. An inverter is employed to convert the stored DC power into AC for practical applications, such as street lighting and public utilities.

I. PROBLEM STATEMENT

With the growing demand for sustainable and renewable energy sources, capturing and harnessing energy from human activity is gaining interest. The Footstep Rechargeable System aims to convert the mechanical energy produced from footsteps into electrical energy that can be stored and used for powering devices like lights, sensors, or low-power electronics in public spaces or commercial buildings.While the idea of capturing energy from footsteps is promising, the existing systems face several challenges that need to be addressed to make the technology efficient and scalable.To develop a footstep rechargeable system that can efficiently capture and store energy from footsteps, while addressing issues of energy conversion, storage, durability, scalability, and cost-effectiveness.

II. METHODOLOGY

The methodology for developing a Footstep Rechargeable System involves a systematic approach to design, implementation, and testing. The goal is to address the challenges of energy conversion efficiency, storage, scalability, and durability while maintaining ease of integration into real-world environments. Analyze the data from field tests to evaluate the long-term feasibility of the footstep rechargeable system.Document all phases of the project, including design, testing, optimization, and real-world performance.

Provide recommendations for improving the system's efficiency, reducing costs, and increasing scalability.

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Continuously monitor the performance of the energy harvesting system and assess the energy output over an extended period.

Analyze data to identify any performance degradation, system failures, or opportunities for further improvement.Deploy the system in high-traffic public areas such as airports, malls, or train stations to test performance under continuous use. Monitor the energy output, user interaction, and system maintenance needs.

IV.BLOCK DIAGRAM

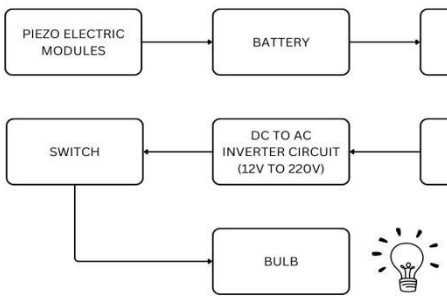

Fig: Block Diagram

V. COMPONENTS USED

1.RECHARGEABLE BATTERY

The rechargeable battery stores the electrical energy generated by the piezoelectric transducers and supplies power to the connected loads when required. It ensures continuous and stable power availability, even in the absence of footstep activity. Lead-Acid batteries typically have a voltage rating of 12V DC and a capacity ranging from 7Ah to 12Ah, depending on the energy storage requirements. They offer a charging cycle of 500 to 1000 cycles and an efficiency of 70% to 85%. In contrast, Lithium-Ion batteries, which are often preferred for higher efficiency and lightweight designs, also have a voltage rating of 12V DC but a slightly lower capacity range of 5Ah to 10Ah. They offer significantly better performance, with charging cycles ranging from 1000 to 3000 and an efficiency rate of 85% to 95%. The advantages of Lithium-Ion batteries include higher energy density, faster charging, and a longer lifespan compared to Lead-Acid batteries.

For both types, the charging voltage typically falls between 13.8V and 14.4V DC, with the charging current varying from 0.1C to 0.3C (C being the battery's capacity in Ah). A PWM or MPPT-based charge controller is generally used for regulated charging. The self-discharge rate is notably lower for Lithium-Ion batteries, ranging from 1% to 2% per month, compared to 3% to 5% per month for Lead-Acid batteries. In terms of discharge, the nominal voltage for both types is 12V DC, with cutoff voltages at 10.5V for Lead-Acid and 11V for Lithium-Ion. The maximum discharge current can reach up to 10C, depending on the battery type and specific application.These batteries are widely used for powering LED streetlights, public utilities, and smart city infrastructure. Additionally, they provide backup power during low foot traffic periods, ensuring reliability and energy efficiency in various systems.

2. PIEZOELECTRIC MODULE

The piezoelectric effect is a phenomenon where certain materials generate an electric charge when subjected to mechanical stress, such as human footsteps. This effect is used in energy harvesting systems to convert mechanical energy into electrical power. Common piezoelectric materials like lead zirconate titanate (PZT), quartz, and polyvinylidene fluoride (PVDF) are known for their high efficiency in energy conversion. A Piezoelectric Module typically consists of multiple piezoelectric transducers arranged in an array to capture and convert energy from footsteps. When pressure is applied to the piezoelectric material, it generates an electric potential, which is then converted into an AC voltage and processed for storage.

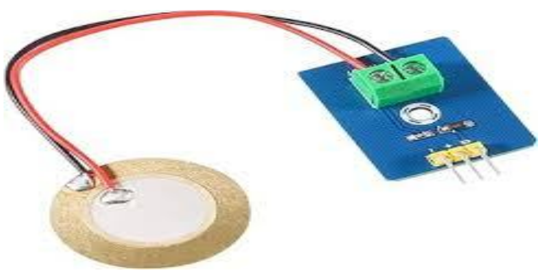

FIG:Piezoelectric Module

The module is made up of several components. The piezoelectric transducer array, which consists of multiple discs or plates, captures the footstep force and converts it into an electrical signal. A mechanical support and load

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distribution layer, typically made of materials like rubber or acrylic, helps ensure even pressure distribution on the transducers. The AC voltage generated is then converted into DC through an AC-DC rectification circuit, and a capacitor smooths the voltage for storage in a rechargeable battery or supercapacitor.

The power output from each piezoelectric transducer is small, usually around 1-10 milliwatts per step, but by combining multiple transducers, the system can generate enough power for small-scale applications, such as streetlight illumination, mobile phone charging, or public displays. The system's efficiency depends on factors like the material used, the force applied, and the design of the piezoelectric tiles. Piezoelectric energy harvesting has several advantages: it is renewable, maintenance-free, compact, and eco-friendly. It can be used in a variety of applications, including smart flooring systems in high-footfall areas, wearable electronics, traffic systems, and healthcare monitoring.

3. INVERTER

An inverter is a crucial component in piezoelectric energy harvesting systems, as it converts the DC power stored in the battery into AC power for use by various electrical devices. Since most consumer electronics and appliances run on AC power, the inverter ensures that the generated electricity is compatible with these devices. In the footstep power generation system, for example, the inverter provides AC power to loads like streetlights, display boards, and charging stations.

The working principle of an inverter involves several stages. First, the stored DC power from the battery is fed into the inverter. Next, a switching circuit, typically using MOSFETs or IGBTs, rapidly turns the DC current on and off to create a pulsed AC signal at the desired frequency (usually 50Hz or 60Hz). The voltage is then increased by a step-up transformer to match the required AC voltage (e.g., 230V). Finally, an LC filter smooths the output to produce a clean AC waveform.

There are different types of inverters, each with varying levels of efficiency and suitability for different applications. A square wave inverter is simple and inexpensive but not suitable for sensitive electronics. A modified sine wave inverter is better but can still cause issues with certain appliances. A pure sine wave inverter, which produces a smooth and consistent waveform, is the most efficient and supports all types of AC loads, including delicate electronic devices. For this project, a pure sine wave inverter is preferred.

The AC voltage output from an inverter follows a sinusoidal waveform, and its power output can be calculated using the formula P=Vrms×Irms×cos(θ)P = V_{rms} \times I_{rms} \times \cos(\theta)P=Vrms×Irms ×cos(θ), where VrmsV_{rms}Vrms is the root mean square voltage, IrmsI_{rms}Irms is the RMS current, and cos(θ)\cos(\theta)cos(θ) is the power factor of the connected load.

The integration of inverters offers several advantages, including efficient power conversion with minimal loss, enhanced compatibility with AC-powered appliances, and improved energy utilization. It also ensures a steady and reliable power supply, which is essential for renewable energy systems.

FIG: inverter

In the context of piezoelectric energy harvesting, inverters are used in applications such as streetlights, charging stations, electronic billboards, and emergency power backup systems, making them a vital part of the overall system.

4. FOOT STEP PLATFORM

A footstep platform is a smart system that creates electricity when people walk on it. It uses piezoelectric materials that produce power when pressed or stepped on. These materials are built into a special floor. As people walk, their steps create pressure, which is turned into electrical energy. This energy can be stored in a battery and later used for things like lights, charging devices, or powering small electronics.

The platform is made of several layers. The top layer is strong and slip-resistant to keep people safe. The middle layer has the piezoelectric materials that produce electricity. Underneath, there's a base layer that keeps the platform stable and spreads the weight. There's also a circuit that changes the electricity from AC to DC and stores it in a battery.

FIG: footstep flatform

The platform works like this: when someone steps on it, pressure is applied to the piezo materials, creating an electric charge. That electricity is collected, converted, and stored. It can then be used to power things like streetlights, mobile chargers, or display boards.

These platforms are useful in many places like smart cities, airports, train stations, malls, and remote areas, where they help provide clean energy just from people walking.

5. AC TO DC CONVERTER

The AC to DC converter is an important part of a piezoelectric energy system. Its main job is to change the AC voltage produced by the piezoelectric transducers into a stable DC voltage that can be stored in a battery or used directly. The converter includes three key components:

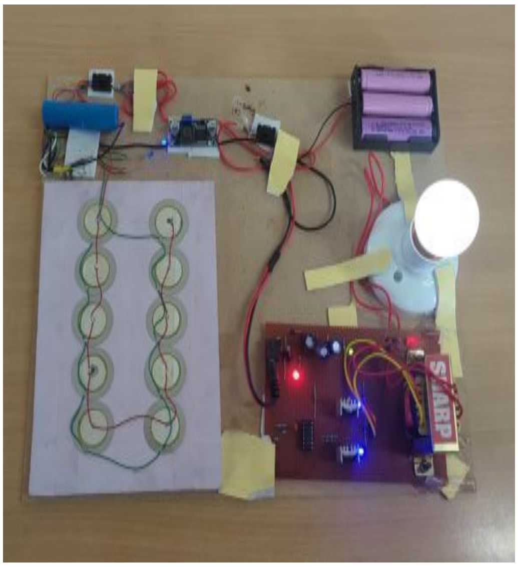
1. A bridge rectifier, made from four diodes (like 1N4007 or 1N5408), turns the AC voltage into a pulsating DC voltage. The input voltage depends on the footstep pressure and can range from 5V to 50V AC, with the output being about 90% of the AC peak voltage.
2. A capacitor filter (usually 1000µF to 4700µF) smooths out the ripples in the DC output to provide a more stable voltage. This helps reduce fluctuations and improves overall performance.
3. A voltage regulator ensures the DC output stays steady and safe for charging batteries or powering devices. Common regulators include LM317, LM7805, and LM7812, or DC-DC boost converters when a higher voltage is needed. These can provide fixed outputs like 5V or 12V, depending on the application.

This system is quite efficient, with a conversion rate between 80% and 95%, and it reduces voltage ripple to less than 5%. The regulated output stays steady with only about ±2% change, even when powering different loads.

6. LOAD

The electricity generated from footstep power systems can be used in several practical ways. One common use is for LED streetlights, which provide lighting in public areas.
These lights usually consume between 5W to 50W and can run on 12V DC or 220V AC (with the help of an inverter). Since they use energy-efficient LED bulbs, they require less power. These typically need 5W to 20W of power and operate at 5V DC for USB charging or 12V/220V AC for larger display screens.
In smart city infrastructure, the system can power IoT devices such as air quality sensors, security cameras, and ticketing machines. These devices vary in power needs, from 10W to 100W, and can use voltages like 5V, 12V, 24V DC, or 220V AC.Finally, in small household appliances, footstep energy can be used for demonstration or experimental purposes. These devices may consume up to 100W and require 220V AC via an inverter. Overall, this system helps support low-power devices efficiently and sustainably in various settings.

RESULT:



CONCLUSION :

The footstep power generation system uses piezoelectric transducers to turn energy from walking into electricity.

This clean and renewable energy can be stored in batteries and used for things like streetlights, mobile charging, and smart city systems.

Key Findings:

- The system successfully turns footstep energy into usable electrical power.
- Using filters and inverters improves the quality of the power output.
- It is eco-friendly, requires no maintenance, and works well in both cities and rural areas.
- The design is affordable and can be expanded for larger uses.

FUTURE SCOPE :

In the future, the footstep power system can be improved by using better materials that produce more energy and last longer. Adding smart technology like IoT can help track energy use and manage power more efficiently. The system can also be expanded to large public areas like malls, train stations, and airports to collect more energy. Combining it with solar or wind power can increase the total energy produced. Better batteries and smart energy management using AI can store and use the power more effectively. Lastly, using low-cost and eco-friendly materials will make the system more affordable and better for the environment.

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