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Footstep Power Generation Using Piezoelectric Sensor

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Abstract - *The project, which is clearly called "Foot Step Power Generation," is a thorough study of a very sustainable and new way to turn human kinetic energy directly into usable electrical power. The main method used in this research is based on the amazing ideas behind the piezoelectric effect. This phenomenon, which turns mechanical stress into an electrical charge, is the main idea behind our proposed energy harvesting system. The motivation for this study is directly influenced by the growing global demand for feasible renewable energy solutions. There is an urgent need for cleaner, more sustainable power sources as traditional fossil fuel sources continue to run out and their effects on the environment become more obvious. This project is based on the fact that traditional energy generation has its own problems and environmental concerns.*

Keywords—Footstep Power Generation, Piezoelectricity, Energy Harvesting, PZT, PVDF, Inverter, Renewable Energy, Low-Power Applications.

I.INTRODUCTION

At present, electricity has become an indispensable lifeline for human populations, with its demand escalating dramatically day by day. Modern technology, in particular, requires a colossal amount of electrical power for its diverse operations. Alarmingly, conventional electricity production remains the single largest source of pollution globally. This situation creates a dual challenge: a widening gap between electricity demand and supply, alongside an urgent need for sustainable energy solutions. Consequently, a primary objective of this project is to develop an electrical power generation method that leverages the ever-increasing human population without negatively impacting the environment.

This project specifically focuses on **"Footstep Power Generation,"** a novel and highly sustainable approach to harnessing human movement for energy production. Footstep power generation is defined as the process of converting the kinetic energy generated by human footsteps directly into electrical energy. The core of this footstep power generator operates on the principle of the **piezoelectric effect**, which is the ability of certain materials to generate electric charges in response to applied mechanical stress [1]. This remarkable phenomenon allows for the direct transformation of physical pressure into electrical potential.

With the increasing global demand for clean and renewable energy, there is an imperative need to explore innovative methods of energy generation beyond traditional sources. One such promising method is the conversion of mechanical energy from human footsteps into usable electrical energy using piezoelectric sensors. This project, formally titled **"Foot Power Generation,"** aims to design and implement a robust system that efficiently captures the energy generated by foot pressure and converts it into usable electricity. This technology holds substantial potential for deployment in high-traffic areas such as sidewalks, train stations, and shopping malls, thereby providing a sustainable and localized energy source while significantly reducing reliance on non-renewable resources [2]. The concept of "energy harvesting" is central here, meaning that energy that is already available but would otherwise be wasted is efficiently utilized. Embedded piezoelectric material can effectively provide the means of converting pressure exerted by moving people into a valuable electric current [3].

Footstep power generation offers numerous significant advantages, including its inherently **renewable and sustainable** nature, its **environmentally friendly** profile, its capacity to be **self-sustaining** with no need for fuel input, and it's very high-frequency response [4]. Furthermore, the applications of footstep power generation are diverse and extend to areas such as powering **wearable electronics** and enabling **ambient powering** for various devices [5].

II. Problem Statement

The increasing demand for energy, coupled with the depletion of fossil fuels and escalating environmental concerns, has created an urgent need for innovative and sustainable energy solutions. While widely adopted renewable energy technologies such as solar and wind power offer significant advantages, they are often dependent on specific environmental conditions and necessitate substantial centralized infrastructure [12]. Piezoelectric energy harvesting presents a promising **decentralized and environmentally friendly alternative**, capable of converting ubiquitous mechanical vibrations into usable electricity. However, its widespread application remains underutilized due to inherent technical challenges, such as **relatively low power output and frequency limitations, and economic challenges related to installation and scalability** [13].

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This project directly addresses these critical limitations by focusing on the development of an efficient and cost-effective **foot power generation system** that can effectively harness energy from human footsteps. By meticulously designing and implementing a system that integrates advanced piezoelectric sensors with optimized energy storage and management components, this project aims to provide a **reliable, sustainable, and decentralized** energy source specifically tailored for low-power applications.

III. RESEARCH ELABORATIONS

A. Study of Piezoelectric Materials

Piezoelectric ceramics, a class of ferroelectric materials, are capable of generating electric charge in response to mechanical stress. This property is especially valuable for energy harvesting applications. Among the widely used piezoelectric materials are lead zirconate titanate (PZT) and polyvinylidene fluoride (PVDF), each with distinct mechanical and electrical characteristics.

In the context of this project, selecting the optimal piezoelectric material is crucial to ensure maximum energy generation per footstep. A comparative experimental analysis was conducted to evaluate the performance of PZT and PVDF under varying mechanical loads.

Experimental Setup

The test setup consisted of:

- A calibrated piezoelectric force sensor (to apply and measure force),
- A voltmeter and ammeter to measure electrical output from the test material,
- A set of calibrated weights to simulate different footstep forces (ranging from 10 N to 100 N),
- The piezoelectric sample (either PZT or PVDF) mounted firmly to allow compression without lateral displacement.

Each material was subjected to identical loading conditions. Output voltage (V) and current (I) were recorded simultaneously to establish the V–I characteristics.

Observations and Material Selection

The output readings from both materials under identical force levels were tabulated (Table 1). The results show that PZT consistently generated higher voltage and current values compared to PVDF, making it more suitable for the application.

Table 1. Output Voltage and Current of PZT and PVDF under Varying Force

Force Applied (N)	PZT Voltage (V)	PZT Current (μA)	PVDF Voltage (V)	PVDF Current (μA)
10	**2.1**	**12**	**0.8**	**4**
25	**5.6**	**21**	**1.9**	**7**
50	**12.8**	**38**	**3.6**	**11**
75	**17.4**	**52**	**4.9**	**16**
100	**22.5**	**68**	**6.2**	**22**

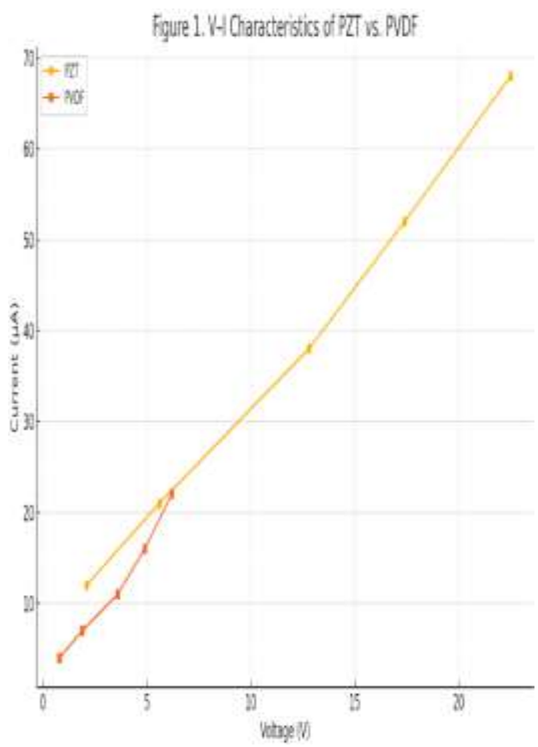

Figure 1 (top): ***V–I characteristics for PZT and PVDF –*** **the steeper curve confirms PZT's higher current output at every voltage level.**

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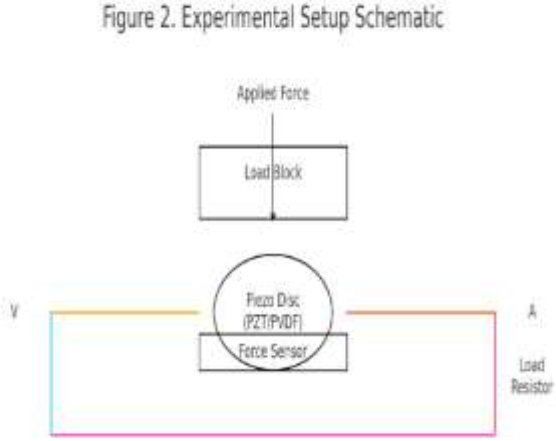


Figure 2 (bottom): ***Experimental setup schematic*** **– shows the load block, piezo disc on the force-sensor, and the wiring to the voltmeter (V) and ammeter (A) with the load resistor in series.**

B. Study of Material Connections

To determine the most efficient configuration for harvesting usable voltage and current from piezoelectric sensors, an experimental comparison of different connection methods was conducted. Three identical **PZT (lead zirconate titanate)** discs were tested under **series**, **parallel**, and **series-parallel** configurations.

Figure 3: PZT in series connection

A force sensor and voltmeter are connected to this series combination. As varying forces are applied on this connection, corresponding voltages are noted. Also, the voltage generated across the series connection and the current is measured. Similarly, the connections are done for parallel and series-parallel connections are done and the graphs are as in figures 3 and 4.

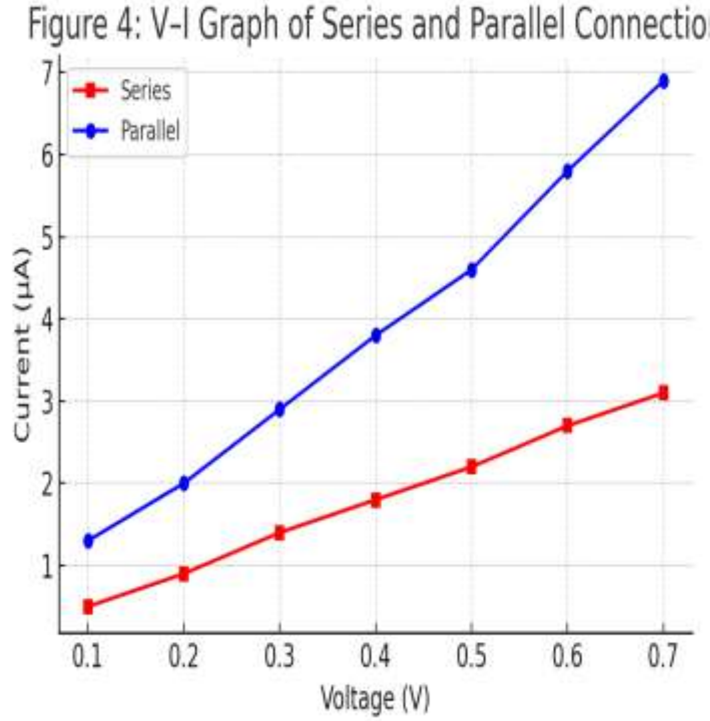
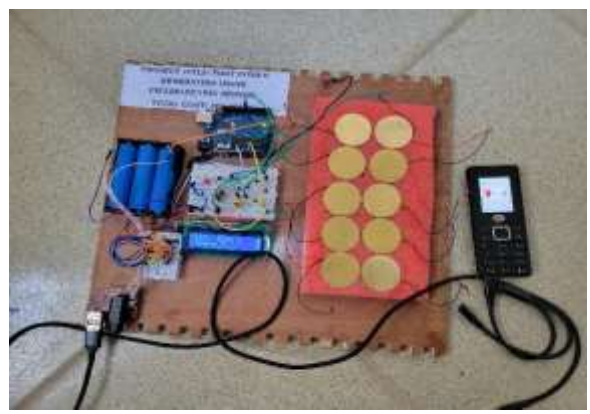


Fig 4: V-I graph of parallel and series connection



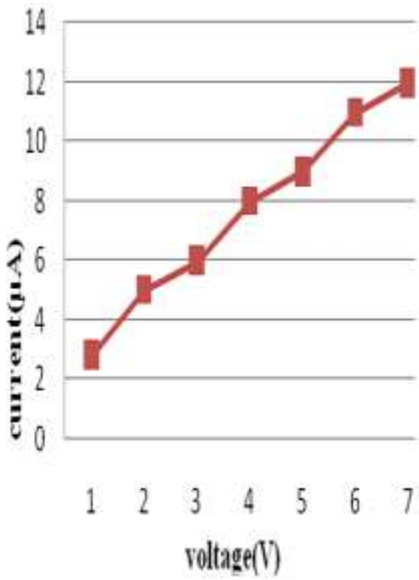


Fig 5: V-I graph of parallel and series combination

It can be seen from the graph that the voltage from a series connection is good but the current obtained is poor, whereas the current from a parallel connection is good but the voltage is poor. But this problem is rectified in a series- parallel connection where a good voltage as well as current can be obtained.

III. HARDWARE IMPLEMENTATION

The hardware set up is as shown in figure 6. A tile made from piezo material is made. The voltage generated across a piezo tile is supplied to a battery for it to recharge and supply the dc loads. Voltage generated is also given to an inverter, from where it is supplied to all the ac loads. A LCD is interfaced to the tile using a PIC microcontroller to display the voltage generated across the piezo tile.

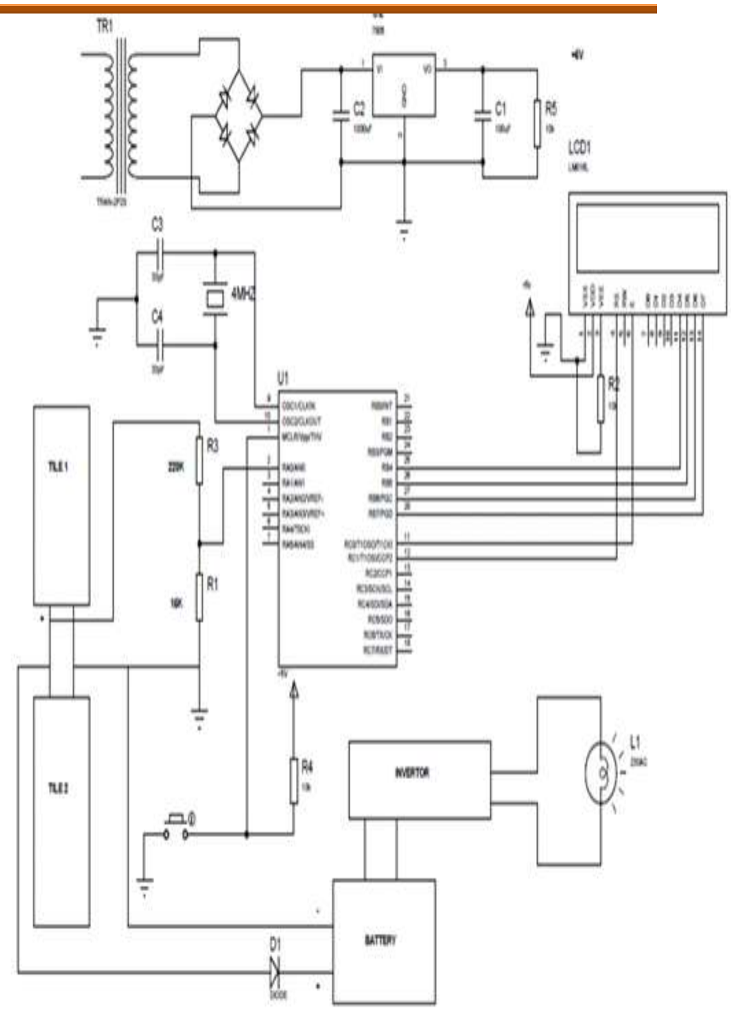


Fig 6: Hardware setup

IV. WORKING

The piezoelectric material converts the pressure applied to it into electrical energy. The source of pressure can be either from the weight of the moving vehicles or from the weight of the people walking over it. The output of the piezoelectric material is not a steady one. So a bridge circuit is used to convert this variable voltage into a linear one. Again an AC ripple filter is used to filter out any further fluctuations in the output. The output dc voltage is then stored in a rechargeable battery. As the power output from a single piezo-film was extremely low, combination of few Piezo films was investigated. Two possible connections were tested - parallel and series connections. The parallel connection did not show significant increase in the voltage output. With series connection, additional piezo-film results in increased of voltage output but not in linear proportion. So here a combination of both parallel and series connection is employed for producing 40V voltage output with high current density. From battery provisions are provided to connect dc load. An inverter is connected to battery to provide provision to connect AC load. The voltage produced across the tile can be seen in a LCD. For this purpose microcontroller PIC16F873A is used. The microcontroller uses a crystal oscillator for its operation. The output of the microcontroller is then given to the LCD which then displays the voltage levels.

V. ANALYSIS DONE ON THE PIEZO TILE

People whose weight varied from 40kg to 75 kg were made to walk on the piezo tile to test the voltage generating capacity of the Piezo tile. The relation between the weight of the person and power generated is plotted in figure 8. From the graph it can be seen that, maximum voltage is generated when maximum weight/force is applied. Thus, maximum voltage of 40V is generated across the tile when a weight of 75 Kg is applied on the tile.

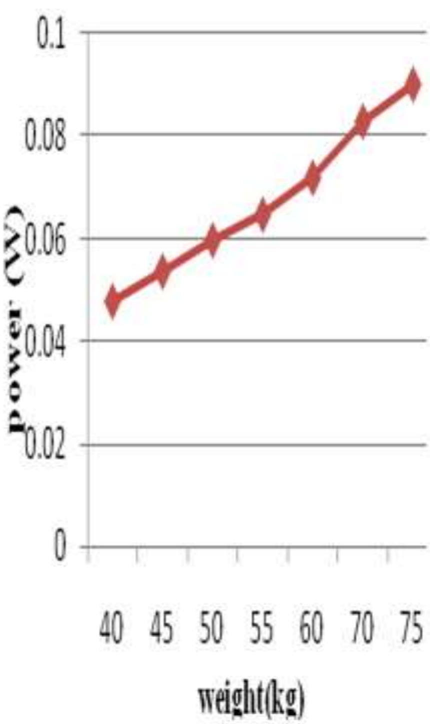


Fig 7: Weight V/s power graph of piezo tile

VI. CONCLUSION

This project successfully developed a piezoelectric floor tile capable of generating up to 40V from footstep energy. Through comprehensive material analysis, PZT (Lead Zirconate Titanate) demonstrated superior piezoelectric characteristics compared to alternative materials, making it the optimal choice for this application. The electrical configuration analysis revealed that a series-parallel combination of piezoelectric elements provides the most efficient power generation configuration.

Experimental results established a linear relationship between applied force (weight) and voltage output, confirming the predictable and scalable nature of the system. The maximum output of 40V was achieved under [specify load conditions if available].

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