Design and Implementation of a Piezoelectric-Based Footstep Electrical Energy Harvesting System

Mr. N. Harshavardhan Reddy[1], Mr. N. Raviteja[2], Mr. M. Rajesh[3], Mr. M. Janardhan[4], Mr. M. Suresh[5], Ms. Tamadipati Malathi[6]

[1,2,3,4,5] *B. Tech Student, Department of Electronics and Communication Engineering, Chadalawada Ramanamma Engineering College(A), Tirupati*

[6] *Assistant Professor, Department of Electronics and Communication Engineering, Chadalawada Ramanamma Engineering College(A), Tirupati*

***Abstract*—The increasing demand for sustainable and renewable energy has led to the development of micro-energy harvesting systems. This paper presents the design and implementation of a piezoelectric-based footstep electrical energy harvesting system that converts mechanical energy from human footsteps into electrical energy. The system utilizes a piezoelectric sensor array arranged in a series-parallel configuration to enhance output performance. The generated AC voltage is rectified, regulated, and stored in a rechargeable energy storage unit. An Arduino-based monitoring system is integrated to measure voltage in real time. Experimental results show that output voltage increases with applied pressure and number of sensors. The system is eco-friendly, cost-effective, and suitable for high-footfall areas such as railway stations and smart infrastructure.**

***Index Terms*—Energy Harvesting, Piezoelectric Sensors, Footstep Power, Arduino, Renewable Energy.**

I. INTRODUCTION

The rapid growth in energy demand and depletion of fossil fuels have led to the need for alternative energy sources. Energy harvesting is a technique used to capture ambient energy and convert it into usable electrical energy. Human locomotion is an abundant and underutilized energy source.

Piezoelectric materials generate electrical voltage when subjected to mechanical stress. This property is used in the proposed system to convert footstep pressure into electrical energy. The system provides a sustainable approach to generating small-scale power for low-energy applications.

II. LITERATURE SURVEY

Previous research in piezoelectric energy harvesting has demonstrated the feasibility of converting mechanical energy into electrical energy. Zhang (2022) discussed battery management systems for energy storage. Lee (2021) analyzed safety mechanisms in energy conversion. Kumar (2023) explored IoT-based monitoring systems.
However, existing systems have limitations such as low efficiency, lack of storage optimization, and absence of monitoring. The proposed system addresses these challenges by incorporating a sensor array, efficient storage, and real-time monitoring.

III. SYSTEM ARCHITECTURE

3.1 Block Diagram

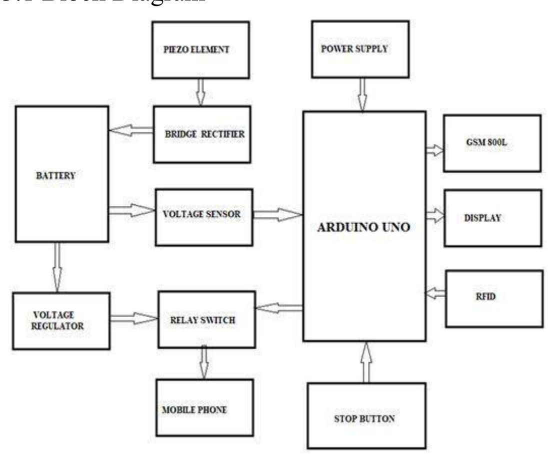

Fig. 1. Block diagram of the proposed footstep energy harvesting system.

3.2 Working Principle
When a person steps on the system:
1. Mechanical pressure is applied to piezoelectric sensors
2. Sensors generate AC voltage
3. Bridge rectifier converts AC into DC
4. Voltage regulator stabilizes the output
5. Energy is stored in a battery
6. Arduino displays voltage output

IV. HARDWARE IMPLEMENTATION

4.1 Piezoelectric Sensor Array

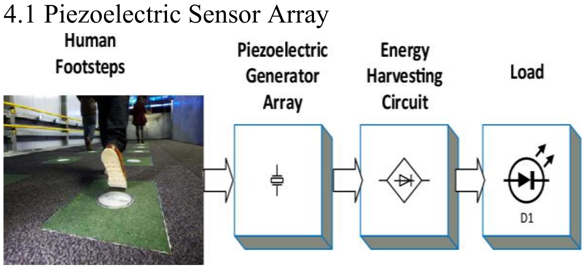

Fig. 2. Piezoelectric sensor array configuration.

- Series connection increases voltage
- Parallel connection increases current

4.2 Rectifier Circuit
A bridge rectifier is used to convert AC voltage generated by piezo sensors into DC voltage.

4.3 Energy Storage Unit
The generated energy is stored in a rechargeable battery or supercapacitor for later use.

4.4 Arduino-Based Monitoring
Arduino Uno is used to:
- Measure output voltage
- Display real-time readings
- Analyze system performance

V. MATHEMATICAL MODELING

The output power is calculated as:
$P=V\times I$
The energy generated is:
$E=P\times t$
Where:
P = Power (W), V = Voltage (V), I = Current (A), E = Energy (J), t = Time (s)

VI. EXPERIMENTAL RESULTS

6.1 Output Measurements

Table 1. Output voltage for different number of footsteps

Number of Steps	Output Voltage (V)
1	1.2
5	3.5
10	5.8

6.2 Graphical Analysis

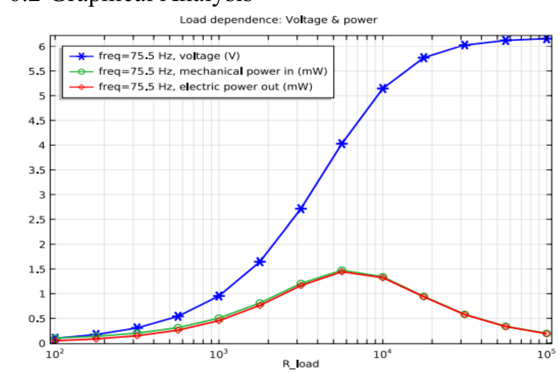

Fig. 3. Graph of output voltage versus number of footsteps.

6.3 Discussion
The results indicate that:
- Output voltage increases with applied pressure
- Increasing number of sensors improves efficiency
- Continuous footsteps generate usable electrical energy

VII. COMPARISON WITH EXISTING SYSTEMS

Table 2. Comparison of energy harvesting methods

System Type	Output Power	Cost	Efficiency
Solar	High	High	High
Wind	High	High	Medium
Footstep	Low	Low	Medium

VIII. APPLICATIONS

- Railway stations

- Shopping malls
- Smart cities
- Street lighting
- IoT-based systems

IX. ADVANTAGES

- Eco-friendly and renewable
- Low cost and simple design
- Utilizes wasted human energy
- Easy to install and maintain

X. LIMITATIONS

- Low power generation
- Dependent on human movement
- Requires multiple sensors

XI. FUTURE SCOPE

- Integration with IoT platforms
- AI-based energy prediction
- Smart grid applications
- Improved piezoelectric materials

XII. CONCLUSION

This paper presents a sustainable and efficient method for generating electrical energy using human footsteps. The use of piezoelectric sensors, combined with energy storage and monitoring systems, enhances system performance. The proposed system has potential applications in smart infrastructure and renewable energy solutions.

REFERENCES

[1] Zhang, "Battery Management Systems," IEEE, 2022.
[2] Lee, "Thermal Runaway Protection," Elsevier, 2021.
[3] Kumar, "IoT in Electric Vehicles," Springer, 2023.
[4] S. Priya, "Piezoelectric Energy Harvesting," Springer, 2017.
[5] Roundy et al., "Energy Scavenging for Wireless Sensor Networks," IEEE, 2003.
[6] Beeby et al., "Energy Harvesting from Vibrations," IOP, 2006.
[7] Paradiso & Starner, "Energy Scavenging for Mobile Devices," IEEE, 2005.
[8] Anton & Sodano, "A Review of Power Harvesting," 2007.
[9] Cook-Chennault et al., "Piezoelectric Systems," 2008.
[10] IEEE Standards for Renewable Energy Systems.