IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

# Harvesting Footstep Energy: Piezoelectric Sensor-Based Power Generation For Sustainable Urban Environments

[1]Pallavi Shelar, [2]Panchsheela Kamble
[1]Research Student, [2]Assistant Professor
Department of Electronic Science,
DES's Fergusson College (Autonomous), Pune, Maharashtra, India

***Abstract***: In the pursuit of sustainable energy solutions, innovation in non-conventional energy resources is paramount. This study delves into the feasibility of footstep power generation, a novel approach to harnessing kinetic energy from human movement. The piezoelectric effect occurs as individuals walk on tiles embedded with piezoelectric sensors. These sensors deform, generating electricity. To stabilize the generated electric charge, an AC-to-DC converter is employed. Utilizing a full-wave bridge rectifier, voltage from both positive and negative cycles is converted into DC, enabling the supply of low DC electric applications or battery charging. The configuration and quantity of piezoelectric transducers directly influence output voltage, with greater numbers resulting in higher voltage production. Experimental analysis includes various configurations such as series, parallel, loop, and series-parallel combinations, revealing optimal performance characteristics. Through the design and implementation of a prototype system equipped with strategically placed sensors, data collection and analysis unveil promising results, showcasing the potential of footstep power generation as a renewable energy source. Furthermore, the study explores the environmental and economic implications, underlining the importance of integrating such solutions into sustainable energy frameworks. This research contributes to the discourse on green energy by presenting a practical approach to leveraging human motion for power generation, thus propelling the transition towards a more sustainable future.

***Keywords:*** Harvesting footstep energy, Piezoelectric sensors, Sustainable urban environments, Kinetic energy, Piezoelectric effect, AC-to-DC converter, Full-wave bridge rectifier, Renewable energy source, Prototype system, Optimal performance, Environmental Implications, Economic Implications, Green energy

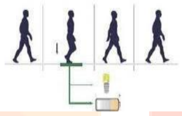
## I. Introduction

The escalating depletion of fossil fuels and non-renewable energy sources has underscored the urgent need for alternative energy solutions capable of replacing dwindling resources while meeting the growing demand for energy. Energy, often defined as the capacity to perform work, is a vital aspect of modern life, with electricity standing as a primary form of energy consumed, steadily rising in tandem with global population growth. The focus of this research is to harness the expanding human populace to significantly augment energy production while mitigating adverse environmental impacts. Importantly, this energy generation method remains independent of climatic conditions.

Efforts to meet electricity demands necessitate the efficient utilization of wasted energy, particularly from human locomotion. The kinetic energy dissipated through human footsteps, manifested as surface vibrations, presents a viable resource for electricity generation. With an average individual taking approximately 2000 to 4500 steps per day, the cumulative footfall holds significant potential to satisfy energy demands. Various methods, including electromagnetic, electrostatic, and piezoelectric mechanisms, facilitate the conversion of footstep-induced vibrations into electrical energy.

Diverse approaches exist for harnessing energy from human or vehicular movement, with innovative techniques targeting ground pressure fluctuations resulting from pedestrian or vehicular traffic. For instance, in the Netherlands, electromagnetic generators embedded within dance floors capture energy from footfallinduced pressure fluctuations. Conversely, Japan has implemented piezoelectric transducers beneath subway ticket machines, capitalizing on foot traffic to generate electricity without complex mechanical structures. These contrasting examples highlight the versatility and adaptability of energy harvesting technologies across different environments and applications. Vibration energy harvesting process begins by extracting mechanical vibrational energy from the surroundings, converting the alternating current (AC) voltage into direct current (DC) voltage. Leveraging the direct piezoelectric effects, wasted energy is effectively transformed into electricity when pressure and strain are applied to piezoelectric materials, thus converting mechanical energy from footsteps. These materials serve as mediums for transferring ambient mechanical vibrations into electrical energy, albeit typically at low levels. Consequently, an interface circuit is essential for converting the AC output into DC, often utilizing a full-wave bridge rectifier followed by waveform filtration and storage in capacitors (Super-capacitors). Deployed strategically in high-traffic areas such as footpaths and stairs, interconnected piezoelectric transducers generate voltage, which powers low-energy devices like road lights and street signs. Due to the modest voltage output, storage in batteries and capacitors precedes practical use.

This study focuses on exploring power generation through the utilization of piezoelectric tiles. These tiles incorporate piezoelectric transducers capable of generating electrical energy by converting pressure applied to them, typically from the weight of individuals walking over them. To enhance power output, five piezoelectric transducer cells are interconnected in a series, parallel and loop configuration. However, the output generated by these transducers is in alternating current (AC) voltage, which necessitates conversion to direct current (DC) for practical use. Hence, a full-wave bridge rectifier is employed to accomplish this conversion, followed by filtration using a smoothing capacitor to mitigate any output fluctuations. Once rectified and filtered, the output is suitable for storage in capacitors or for powering low-energy devices.



## II. RESEARCH METHODOLOGY

1. **Electricity from footsteps, SS Taliyan, BB Biswas, RK Patil, GP Srivastava, TK Basu, 2010.**
   This paper discusses the basic engineering and operational mechanism of piezo crystal, engineering analysis of the model, working of piezo crystal and energy generation through footsteps.

2. **Potentials of piezoelectric and thermoelectric technologies for harvesting energy from pavements, Lukai Guo, Quing Lu, 2017.**
   This paper discusses the cost- effectiveness analysis of energy harvesting pavement technologies. It estimates electrical energy generation from a pavement network by two technologies cost calculation and estimating needs. Cost analysis and estimation of energy production based on piezoelectric technology.

3. **Floor tile energy harvester for self-powered wire- less occupancy sensing, Nathan Sharpes, Dušan Vučk- ović and Shashank Priya, 2016.**
   This paper presents details about designing and optimum structure of the piezoelectric product. Also proposed a suitable structure for product design for commercialization and design of outer shell circuit design and structure

4. **Green sidewalk makes electricity – one footstep at a time, George Webster, 2011.**
   This paper studies the power generation method. Reviews of the public and studies introduction of an alternate source of energy in the market.

5. **An Investigation into energy generating tiles – Pavegen, Zhen Liang Seow, Song Tao Chen, and Nor Bainin Khairudin, 2011.**
   This paper provides an idea of commercialization of the piezoelectric based energy production in a live scenario.

6. **Future uses of the piezoelectric effect for energy production, Zack Mester and Guilherme Tamassia, 2012.**
   This paper discusses the economic aspects of piezoelectricity, drawbacks of piezo electricity and other innovative techniques of piezoelectric generation. Also studied how to minimize the potential drawbacks of piezoelectricity and improve the efficiency of energy generated.

7. **Feasibility study for using piezoelectric energy harvesting floor in buildings' interior spaces, Adnan Mohamad Mahmoud Yousif, 2017.**
   In this paper, the feasibility of piezo electric tiles in the interior of buildings is studied. Analysis of energy transformation with the help of piezo electric tiles is done. Also studied the feasibility of energy-generating tiles in the interior of buildings and also at low pedestrian spaces like apartment case by using harvesting floor tiles in a different way to generate and save energy.

8. **Application of piezoelectric transducer in energy harvesting in the pavement, Xiaochen Xu, Dongwei Cao, 2017.**
   This paper states that utilizing piezoelectric technology in road energy harvesting is feasible and has a bright future. It defines the working mechanism in detail and the use of piezoelectric in energy harvesting.

9. **Electricity from footsteps, S.S. Taliyan, B.B. Biswas, R.K. Patil, and G.P. Srivastava, 2013**.
   This paper presents the possibility of the generation of electricity from footsteps. Working model of the footstep based energy generator. The article has given a detailed working model and functioning of the footstep-based electricity generating system. This is an energy-efficient way of producing electricity as walking is one of the most common things, we do in the day to day life**.**

10. **A review of power harvesting from vibrations using piezoelectric materials, Henry A. Sadano, Daniel J. Inman, and Gyuhae Park, 2004.**
    This paper analyses harvesting power from vibration using a piezoelectric material. Various aspects of energy harvesting based on mechanical and electric components are investigated. With the advancements in technology harvesting, electricity with the help of piezoelectric materials will be more efficient.

11. **Piezoelectric energy generation in India : An empirical investigation, Hari Anand and Binod kumar Singh**
    This paper analyses total power production in India, also importance of adaptability of piezoelectric energy harvesting model which is cost-effective and easy to implement. It also gives shares of energy generation in India in table and pie chart form.

## III. THEORETICAL FRAMEWORK

The meaning of a Piezo-electric transducer is an electrical transducer which can change over any type of physical quantity into an electrical signal, which can be utilized for measurement. An electrical transducer which involves properties of piezoelectric materials for transformation of actual amounts into electrical signals is known as a piezoelectric transducer.
It uses piezoelectric effect for the measurement of the changes in any quantity by conversion of the energy to electric charge Piezoelectric materials show the property of piezoelectricity, as per which on the application of a mechanical pressure or strain prompts the generations of an electric voltage relative to the applied pressure. This produced electric voltage can be measured using voltage measuring instruments to compute the value of stress or strain applied to the material.

Features and Specifications:

1. Impedance: ≤500Ω;
2. Voltage: ≤30Vp-p;
3. Operating temperature: -20°C~+60°C
4. Storage temperature: -30°C~+70°C
5. Low Soldering temperature
6. Strain sensitivity: 5V/µƐ
7. Material: Quartz (mostly used)

**Fig 2.a**

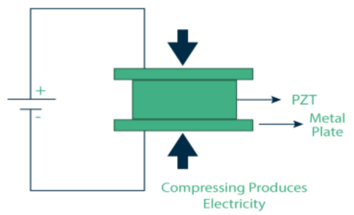



**Fig 2.b: working of piezo sensor**

### Working of Piezoelectric Transducer

Piezoelectric Transducer works with the guideline of piezoelectricity. The essence of piezoelectric material, normal quartz, is covered with a thin layer of conducting material like silver. At the point when stress has applied the particles in the material move towards one of
the leading surface while getting away from the other. This outcome in the age of charge. This charge is utilized for adjustment of stress. The extremity of the delivered charge relies on the heading of the applied

pressure. Stress can be applied in two structures as Compressive pressure and ductile pressure as shown in figure 2.b

**Piezoelectric Transducer Circuit:** The working of a fundamental piezoelectric transducer can be explained by the below figure.

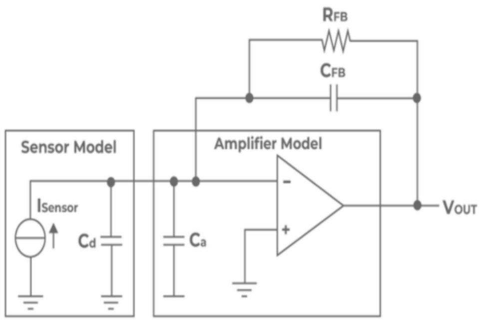



**Fig.3.2 Signal conditioning of piezo sensor**

Here quartz crystal coated with silver is utilized as a sensor to generate a voltage when stress is applied on it. A charge enhancer is utilized to gauge the delivered charge without dissemination. To draw exceptionally low current the obstruction R1 is extremely high. The capacitance of the lead wire that associates the transducer and piezoelectric sensor additionally influences the alignment. So the charge intensifier is typically positioned extremely close to the sensor.

So in a piezoelectric transducer when mechanical pressure is applied a corresponding electric voltage is produced which is enhanced utilizing charge speaker and utilized for adjustment of applied pressure.

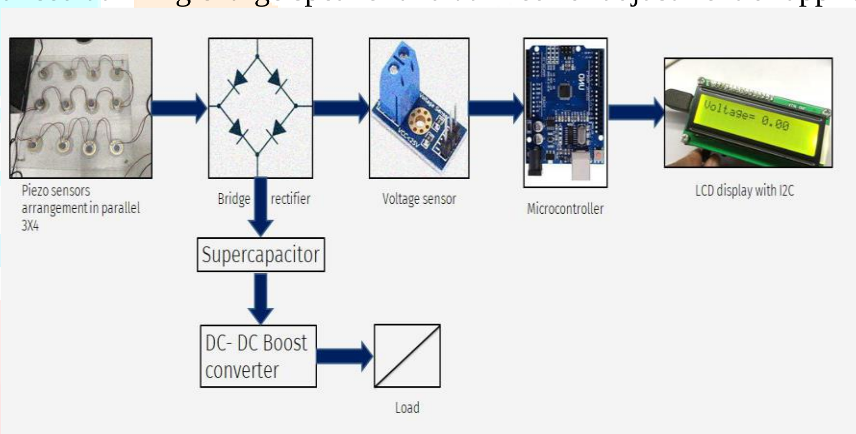



**Fig.3.3 System block diagram**

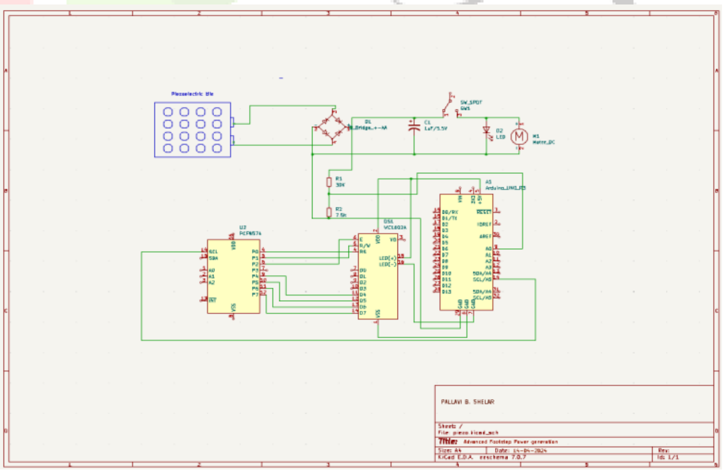


**Fig.3.4 Schematic of proposed system**

In the research method, a Quartz crystal piezoelectric transducer has been used to harvest locomotive energy from the footsteps. When the pressure is applied on the piezo sensor its crystalline structure changes and deformation happens in its shape and output is obtained in the form of voltage. The common output voltage is nearly 0-14V AC voltage. However at instant impact on the transducer, it can achieve until 26V while the output current is 1mA of a single piezoelectric sensor.

The experimental setup, as illustrated in the schematic diagram (Figure 1), comprises a piezoelectric sensor (PZ1) connected to a bridge rectifier (BR1). The piezoelectric sensor is utilized to convert mechanical stress into electrical energy. The positive terminal (P+) and negative terminal (P-) of the sensor feed into the bridge rectifier, which consists of four diodes arranged in a specific configuration to convert the alternating current (AC) output of the sensor into direct current (DC).

Post rectification, the DC output is smoothed by a capacitor (C1) rated at 4.7 μF and 25V. The capacitor helps in reducing the ripple voltage, thereby providing a more stable DC output. This smoothed voltage is then passed through a resistor (R1) with a resistance value of 330 ohms to limit the current and protect the subsequent load. The load in this setup is represented by a light-emitting diode (LED, D1), which serves as a visual indicator of the presence of the rectified and smoothed electrical signal generated by the piezoelectric sensor.

In the practical implementation of this circuit, depicted in the breadboard assembly (Figure 2),use of two different multimeter are employed to measure the voltages at different points in the circuit. The multimeter on the left is configured to measure the voltage across the piezoelectric sensor, indicating a value of 0.028V, which represents the sensor's output before rectification. The multimeter on the right measures the voltage across the LED, showing a value of 0.622V, which confirms the presence of a rectified and regulated output voltage sufficient to drive the LED.

This dual measurement setup not only validates the operation of the piezoelectric sensor and rectifier circuit but also ensures accurate monitoring of the voltage levels throughout the circuit. The alignment of theoretical design and practical implementation highlights the effectiveness of the piezoelectric sensor in generating a usable electrical output from mechanical stress, as evidenced by the illumination of the LED. This methodological approach is crucial in confirming the viability of piezoelectric sensors for energy harvesting applications.

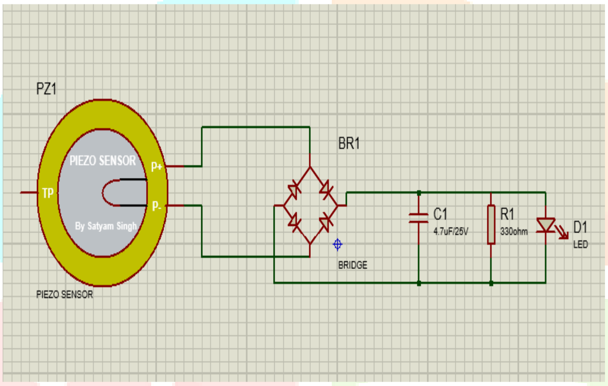



Fig.3.5 Piezo sensor with bridge rectifier

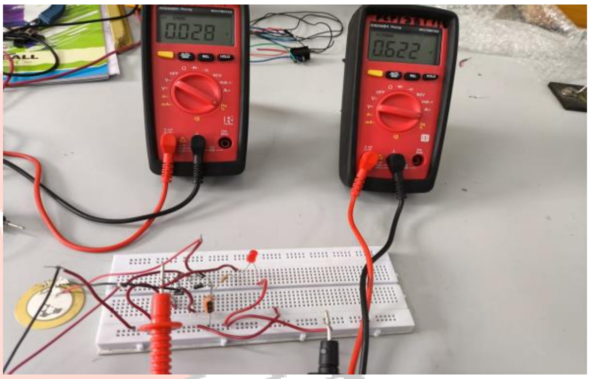


Fig.3.6 Experimental setup

## IV. RESULTS AND DISCUSSION

### 4.1) Result and Analysis

Before connecting the output of the piezoelectric transducer to the full bridge rectifier, it's essential to rectify and filter the AC waveform it produces. This ensures that the output is suitable for powering DC loads or storing energy effectively. Figure 3 illustrates the raw output of the piezoelectric transducer, which requires processing before further use.

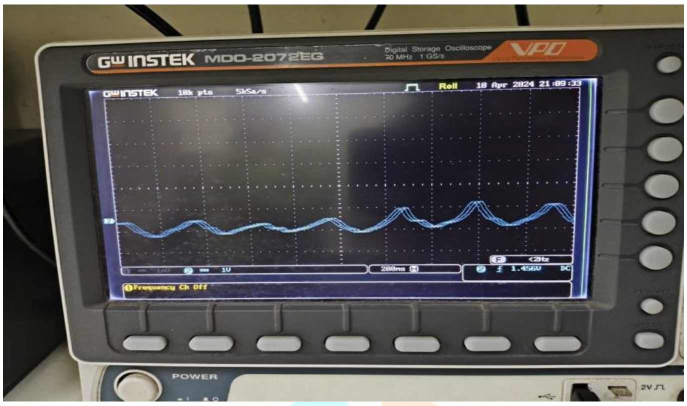



**Fig. 4.1 The output of the piezoelectric transducer before rectification**

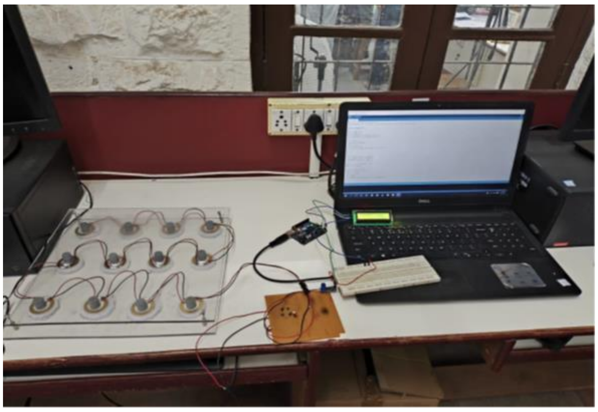


**Fig 4.9 Experimental setup**

### 3.2) Observations

**Table (1) Observation Table**

| AC Voltage (Volt) | Rectified DC voltage (Volt) | Capacitor voltage (Volt) | Load voltage(LED) mV |
|---|---|---|---|
| 1 | 1.5 | 1.8 | 31.3 |
| 1.2 | 2.6 | 2.03 | 40.4 |
| 1.3 | 3.1 | 2.5 | 45 |
| 1.5 | 3.4 | 2.6 | 55 |
| 2 | 3.5 | 4 | 67 |

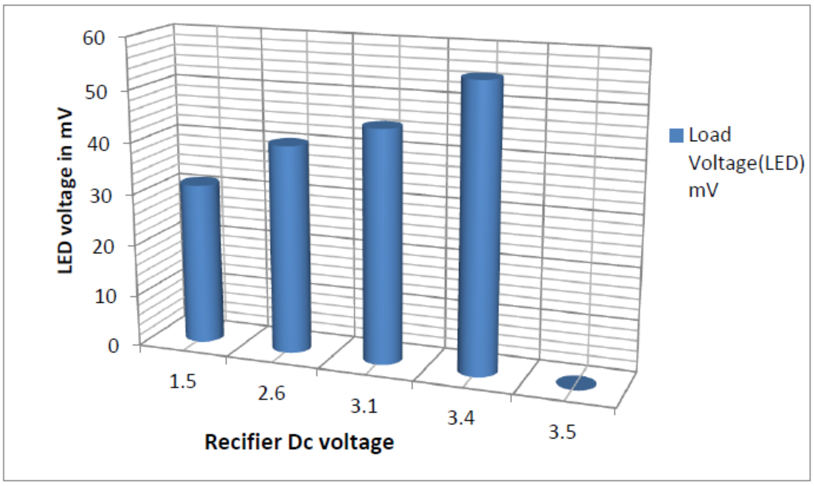



**Fig.4.2 Graph of DC voltage Vs Load voltage**

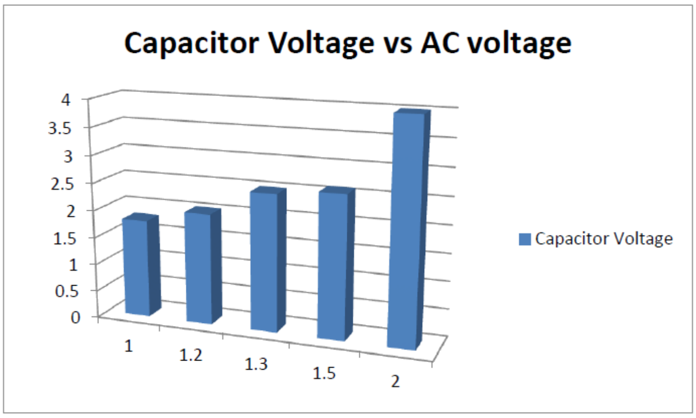



Fig.4.3 graph of Capacitor voltage Vs AC voltage

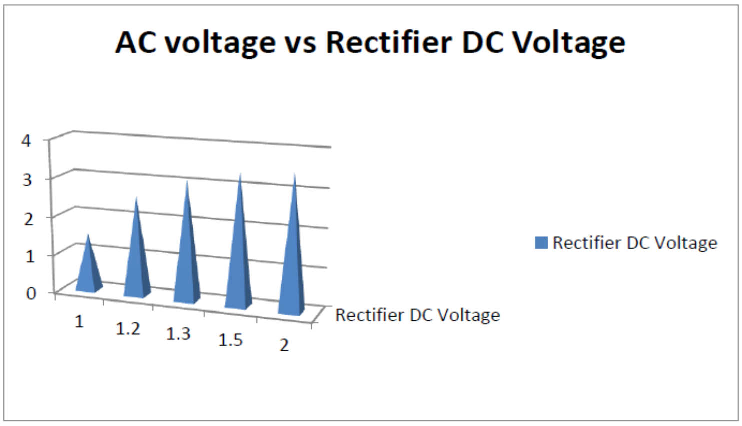



Fig 4.4 graph of AC voltage Vs Rectified DC voltage

[1] Piezoelectric sensors in parallel :

**Table 2) Parallel piezo readings**

| AC Voltage(volts) | Rectified DC voltage(volts) | Capacitor voltage(volts) |
|---|---|---|
| 1 | 3.8 | 3.4 |
| 2 | 4 | 4 |
| 3 | 5.3 | 5.3 |
| 4 | 6.14 | 6.17 |

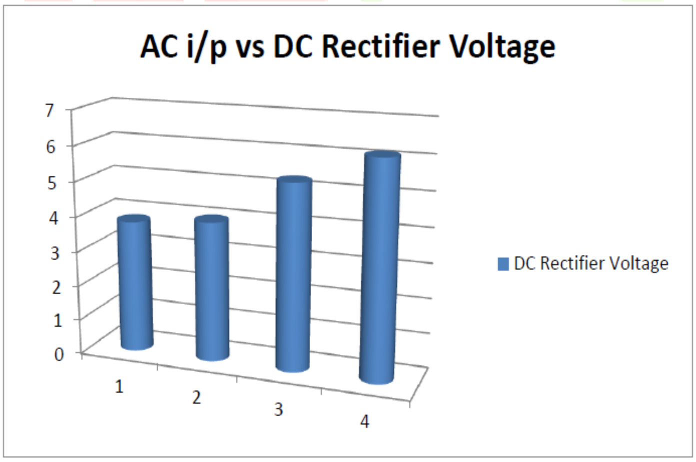



Fig.4.5 graph of AC i/p Vs DC voltage

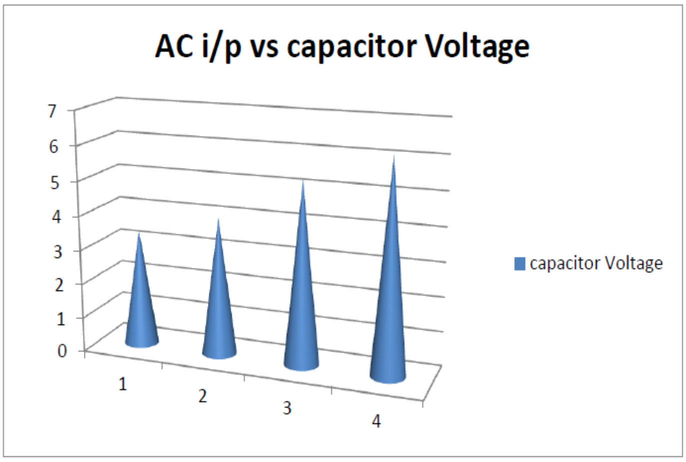



Fig 4.6 graph of AC voltage Vs Capacitor voltage

[2] Piezoelectric sensors in Series :

**Table 3) Piezo in series**

| AC Voltage(volts) | Rectified DC voltage(mili volts) | Capacitor voltage(volts) |
|---|---|---|
| 1 | 77 | 4.1 |
| 2 | 162 | 4.04 |
| 3 | 198 | 5 |
| 4 | 220 | 7 |

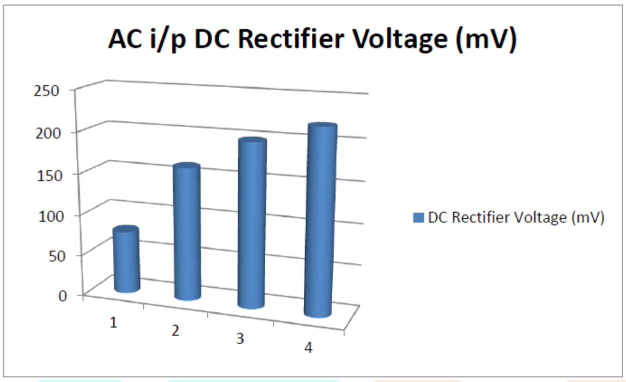



**Fig.4.7 graph of AC voltage Vs DC voltage**

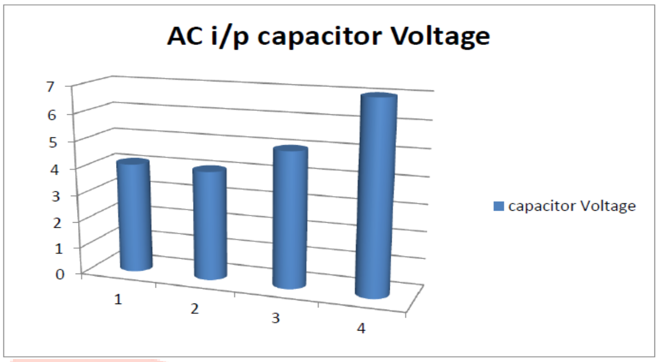



**Fig 4.8 graph of AC voltage Vs Capacitor voltage**

## V. ACKNOWLEDGMENT

We express our gratitude to Dr. Ravindrasinh Pardeshi, Principal, Fergusson College (Autonomous), Pune, Dr. Kalpana Kulkarni, M.Sc cordinator, Department of Electronic Science, Fergusson College (Autonomous), Pune, who have helped us with their knowledge, resources, motivation, and all other kinds of support.

**References:**

1. S.S.Taliyan, B.B. Biswas, R.K. Patil and G. P. Srivastava, *Electricity from Footsteps*, Reactor Control Division, Electronics & Instrumentation Group And T.K. Basu IPR, Gandhinagar.
2. Gopinath, R., Lavanya, M., & Arivalagan, M. (2018). Power generating using human foot step with piezo electric sensor and treadmill. *International Journal of Pure and Applied Mathematics*, 119(16), 3171-3182. ISSN: 1314-3395. Available at: http://www.acadpubl.eu/hub/.
3. Anand, H., & Singh, B. K. (2021). Piezoelectric energy generation in India: an empirical investigation. *Environmental and Health Sciences*, doi:10.1515/ehs-2020-0002. Available at: https://doi.org/10.1515/ehs-2020-0002.
4. *Design Study of Piezoelectric Energy- Harvesting Devices for Generation of Higher Electrical Power Using a Coupled Piezoelectric-Circuit Finite Element Method*, IEEE Transactions on Ultrasonic's, Ferroelectrics, and Frequency Control, vol. 57, no. 2, February 2010.
5. Nik Ahmad Kamil Zainal Abidin, Norkharziana Mohd Nayan, M. M. Azizan, Azuwa Ali, Nuriziani Hussin, N. A. Azli, and N. M. Nordin. "The simulation analysis of piezoelectric transducer with multi-array configuration." *Journal of Physics: Conference Series*, vol. 1432, no. 1, 2020, p. 012042. doi:10.1088/1742-6596/1432/1/012042.
6. Hao, Hongmei, Xudong Zhao, Linchuan Yang, Chunxiang Xu, Shijun You, Nan Zhang, Huan Wang, Haofei Zhao, Xiaoxu Zhang, and Fan Bai. "Performance analysis and optimization of an

innovative solar-assisted combined cooling, heating and power system driven by photovoltaic-thermal collectors, flat plate collectors and biomass." *Energies*, vol. 16, no. 9, 2023, p. 1631. doi:10.3390/en16091631.

7. Hong, Lim Chee, Najib Al-Fadhali, Huda Majid, MSM Gismalla, Jameel A. A. Mukred, and Najmaddin Abo Mosali. "Footstep Power Generation Using Piezoelectric Transducers." Progress in Engineering Application and Technology, vol. 3, no. 1, 2022, pp. 454-469. doi:10.30880/peat.2022.03.01.046.
8. Cornell Dubilier, "Type EDL, Electric Double Layer Supercapacitors: Ultra High Capacitance, Small Case Size Options," datasheet, Cornell Dubilier, New Bedford, MA, USA. [Online].
9. Kiran Boby, Aleena Paul K, Anumol.C.V, Josnie Ann Thomas, Nimisha K.K Dept of EEE, MACE, Kothamangalam, *Footstep Power Generation Using Piezo Electric Transducers*, International Journal of Engineering and Innovative Technology (IJEIT) Volume 3, Issue 10, April 2014,264-267.