# Low-Cost Mechanical Footstep Power Generator for Public Spaces

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## ABSTRACT

The growing need for clean and alternative energy solutions has encouraged the development of systems that can utilize wasted energy in everyday life. Human footsteps are a reliable source of mechanical energy, especially in crowded public places. This paper presents the design and fabrication of a low-cost mechanical footstep power generator using a rack and pinion mechanism coupled with a DC generator. The system captures the mechanical energy produced during walking and converts it into electrical energy, which is stored in a battery for lighting or other small load applications. The prototype is simple, cost-effective, and environmentally friendly, making it ideal for use in locations like railway stations, bus stops, parks, and shopping malls. The experimental results demonstrate that this system can generate useful amounts of electricity from everyday human activities, promoting sustainable urban energy solutions.

**Keywords**: Footstep energy harvesting, Rack and pinion mechanism, Low-cost power generation, DC generator, Public spaces, Sustainable energy.

## 1. INTRODUCTION

Energy is one of the basic needs for human survival and development. With increasing industrialization, urbanization, and population growth, the demand for energy is rising rapidly all over the world. Traditional energy sources like coal, petroleum, and natural gas are being consumed at a high rate and are causing major environmental issues such as air pollution, global warming, and climate change. Therefore, there is an urgent need to explore alternative, non-conventional, and eco-friendly sources of energy that are sustainable for the future.

Among various renewable energy sources, the energy wasted through human movement remains largely untapped. Every day, in crowded public places such as railway stations, bus stands, parks, malls, and schools, thousands of people move around, unknowingly wasting a considerable amount of mechanical energy. If this energy can be captured efficiently, it can contribute significantly to our energy needs without causing pollution or requiring any fuel.

Several methods have been researched for harvesting energy from human activities. Piezoelectric materials, hydraulic systems, and electromagnetic generators have been used in different designs. However, many of these systems are costly, complex, or not suitable for large-scale public installations. Mechanical systems, such as rack and pinion mechanisms, provide a simple, low-cost, and efficient method to convert vertical footstep motion into rotational motion, which can then drive a generator to produce electricity.

In this paper, a low-cost mechanical footstep power generator is designed and fabricated. The system uses a rack and pinion arrangement connected to a 12V DC generator. As a person steps on the platform, their weight moves the rack, which rotates the pinion and produces electricity. The generated power is stored in a battery and can be used for lighting or charging small devices. The design is simple, easy to maintain, environmentally friendly, and especially suitable for crowded public spaces where large numbers of footsteps can generate significant energy over time.

The main objective of this project is to utilize wasted human mechanical energy in a practical, cost-effective, and eco-friendly manner. By promoting such technologies, we can move towards greener cities and reduce our dependence on conventional fossil fuel-based energy systems.

## 2. LITERATURE REVIEW

The search for sustainable and alternative energy sources has led to the exploration of human locomotion as a potential method for energy harvesting. Various techniques have been proposed to convert the mechanical energy from footsteps into electrical energy for low-power applications.

**Piezoelectric Energy Harvesting:** Piezoelectric materials are widely studied for their ability to generate electricity under mechanical stress. Hossain and Uddin (2018) developed a system using piezoelectric sensors embedded in shoes to capture energy from human movement. Similarly, Jayasekara et al. (2017) proposed a design that converts kinetic energy from footsteps into electrical energy, focusing on its application for low-power devices.

**Electromagnetic and Airflow Harvesting:** Fu et al. (2015) introduced a miniaturized wind turbine-based energy harvester integrated into footwear, converting foot-strike-induced airflow into electricity with a peak output of 6 mW. This system demonstrates the feasibility of energy harvesting without compromising comfort.

**Commercial Implementations:** A notable real-world application occurred in 2008, when a piezoelectric power mat was installed at Tokyo's Shibuya train station to generate electricity from pedestrian footsteps, powering holiday lights and LED boards. This showcased the potential for footstep energy harvesting in high-traffic areas.

These studies highlight diverse methods for footstep energy harvesting, each with its own benefits and limitations. Despite promising results from piezoelectric and electromagnetic systems, challenges such as material durability and energy conversion efficiency remain. This paper proposes a low-cost mechanical footstep power generator using a rack and pinion mechanism to address these issues, offering a practical solution for energy generation in public spaces.

## 3. DESIGN AND METHODOLOGY

The design of the Low-Cost Mechanical Footstep Power Generator focuses on converting mechanical energy from human footsteps into usable electrical energy using a simple, cost-effective, and efficient system. This section describes the design, components, and working principle of the system.

### 3.1 SYSTEM DESIGN

The system is built around a rack and pinion mechanism that efficiently converts the vertical motion of a footstep into rotational motion, which is then used to generate electricity through a DC generator as shown in figure 3.1. The design was aimed at creating a robust and affordable solution, suitable for public spaces such as railway stations, parks, and shopping malls.

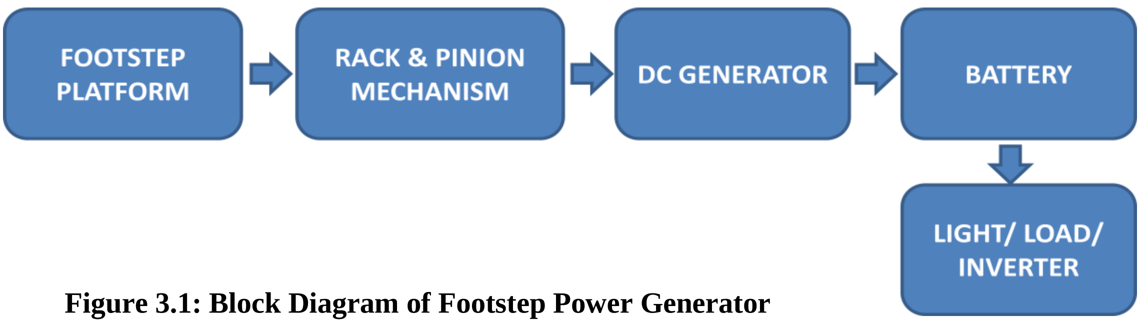


**Figure 3.1: Block Diagram of Footstep Power Generator**

1. **Footstep Platform:** The footstep platform is designed to compress under the weight of a person, initiating the mechanical motion of the system.
2. **Rack and Pinion Mechanism:** As the platform moves downward, a rack attached to it engages with a pinion gear. This converts the linear movement into rotational motion.
3. **DC Generator:** The rotating pinion drives the shaft of a DC generator, converting mechanical energy into electrical energy.
4. **Energy Storage:** The electricity generated is stored in a rechargeable battery to be used for powering small loads such as LEDs or other low-power devices.
5. **Load/Output:** The stored energy is then used to power a load, such as lights, or to supply power to a small inverter for other applications.

### 3.2 WORKING PRINCIPLE

The footstep power generator operates on a simple mechanism that generates electricity during the compression and rebound of the footstep platform:

1. **Footstep Compression**: When a person steps on the platform, it compresses the springs placed beneath it, causing the rack to move vertically downward.
2. **Rack and Pinion Engagement**: The vertical motion of the rack engages the pinion gear, which rotates as a result of the interaction with the rack.
3. **Power Generation**: The pinion's rotational motion drives the DC generator, which converts the mechanical energy into electrical energy.
4. **Foot Release (Rebound)**: When the foot is lifted, the compressed springs push the platform back up, causing the pinion to rotate in the opposite direction, generating electricity again.

Thus, the system generates electrical energy both during the compression phase (footstep) and during the rebound phase (foot release).

### 3.3 COMPONENTS USED

The main components used in this footstep power generator system are:

**Table 3.1: Components Required**

| Sl. No. | Component | Material / Details |
|---|---|---|
| 1 | Base and Upper Plates | Mild Steel |
| 2 | Springs | Alloy Steel Wire |
| 3 | Rack and Pinion Arrangement | Mild Steel |
| 4 | Shaft | Mild Steel |
| 5 | Spur Gears | Mild Steel |
| 6 | Supporting Rods | Mild Steel Pipes |
| 7 | DC Generator | 12 Volt Permanent Magnet Type |
| 8 | Bolts and Screws | Standard Size for Assembly |

**Figure 3.2: Base Assembly**

**Figure 3.3: Upper Assembly**

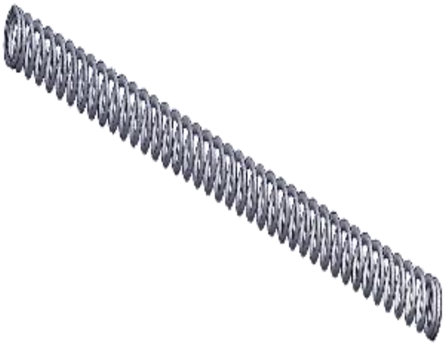

**Figure 3.4: Spring**

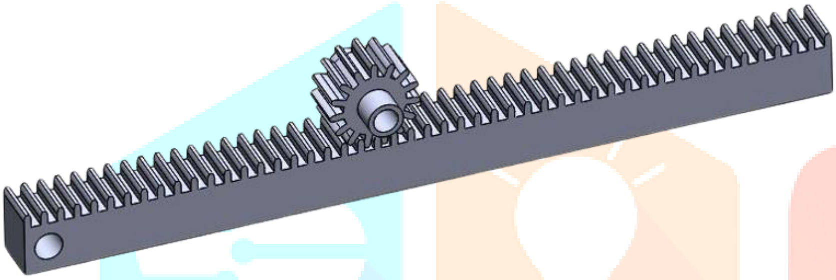

**Figure 3.5: Rack & Pinion**

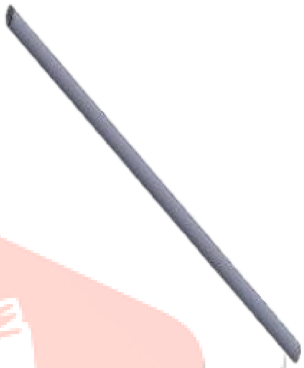

**Figure 3.6: Shaft**

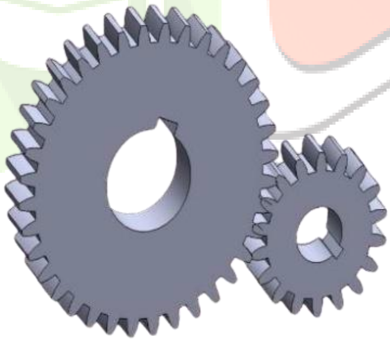

**Figure 3.7: Spur Gears**

**3.4 ASSEMBLED DIAGRAM**

The final assembly of the Low-Cost Mechanical Footstep Power Generator is shown in the figure 3.8. This represents how all components are connected and integrated into the system:

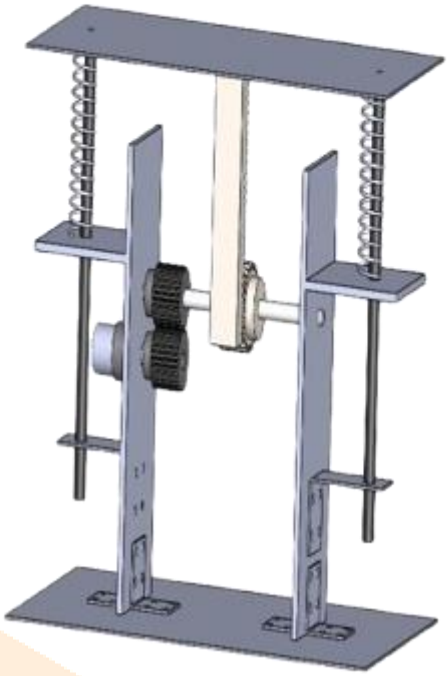

**Figure 3.8: Assembled Unit**

## 4. OUTPUT POWER CALCULATION

The mechanical work done by a footstep is calculated using the basic formula:

Work Done (Joules) =Force (N) × Distance (m)

Where:

- Force = mass × gravity (9.81 m/s²)
- Distance = spring compression during footstep

**Case 1:** (65 kg person)

- Force = Mass × gravity = 65 × 9.81 = **637.65 N**
- Distance = Spring compression = **8 cm = 0.08 m**
- Work done = Force × Distance = 637.65 × 0.08 = **51.012 Joules**
- If one step happens in 1 second,

  Output Power = 51.012 / 1 = **51.012 Watts** (theoretical)

**Case 2:** (80 kg person)

- Force = 80 × 9.81 = **784.8 N**
- Distance = **12 cm = 0.12 m**
- Work done = 784.8 × 0.12 = **94.176 Joules**
- Output Power = 94.176 / 1 = **94.176 Watts** (theoretical)

**Electrical Calculation:**

The generator used is rated at **12V**, **250mA**

Thus,

- Maximum Electrical Output = Power output at full load = 12V × 0.25A = **3 Watts**
- Realistic output from one step ≈ **2V to 3V** depending on speed and force.

## 5. CONCLUSIONS

The mechanical footstep power generator successfully demonstrates the conversion of human kinetic energy into electrical energy using a rack and pinion mechanism. The system is simple, eco-friendly, and easy to install. It works effectively without needing any external fuel, making it a clean energy source.

By installing this system at busy public locations, we can save a lot of energy that is otherwise wasted. Although the power output from a single unit is small, installing many units together can generate significant electricity, helping to solve part of the power shortage problem. This technology is an important step towards a greener future.

The system can be improved by optimizing the mechanical design and using a higher-capacity generator to increase efficiency. Connecting multiple units together can generate more significant power for larger applications. Future developments may also focus on integrating this setup with solar panels for hybrid energy harvesting and using advanced energy storage solutions to enhance overall performance.

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