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An Analysis of the Design and Development of Power-Generating Tiles

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Abstract
In this work, a rack and pinion system is utilised to generate electricity by utilising force obtained while walking on steps. It creates electrical energy via mechanical systems. The produced electricity is stored in a battery and utilised to power the linked lighting loads. This is one of the small and efficient power generation systems that may be simply put in a variety of locations. The primary operating concept is based on the application of spring force to transform mechanical energy into electrical energy. This electrical energy is stored in the inverter's rechargeable battery. This inverter is also used to convert dc to ac. This concept encourages non-traditional energy sources by producing power from human footfall. This article discusses the whole mathematical computations and design. Its hardware model is also being constructed to validate the mathematical design.

Keywords: *Generator, inverter, pinion, rack, and electricity generation.*

INTRODUCTION

The proposal for using waste energy of foot power with human locomotion is especially relevant and significant for densely populated nations like India, where the mobility of its people may be used to generate electricity from their footfall. Roads, train stations, and bus stops are all packed in India, and millions of people travel around the clock. As a result, with the application of this promising technology, a great amount of electricity may be generated. Several modest setups are put beneath the walking platform throughout this operation. When people walk on this platform, their bodies compress the arrangement, which turns a generator and stores the current created in a battery.

More energy will be generated when individuals walk around more. The idea for this design is that the non-conventional energy system is very important to our nation at this time and should be utilised. Non-traditional energy such as footfall need no fuel input power to create electrical power. In this system, a basic driving mechanism, such as a rack and pinion assembly, is employed to generate power by utilising force obtained when walking on stairs. Power generation is important, although it has few early cost-effective elements. The following are the work's objectives:

1. Using the human foot to create power.
2. Promote non-traditional energy sources.
3. To save power for later use.
4. To create power at the lowest possible cost.

LITERATURE SURVEY

The importance and need for electricity are explored in [1]. The primary worry of today is energy. There are several techniques for producing energy, such as conventional and non-conventional methods. [2] discusses numerous uses of mechanical foot step power generating, such as in colleges, temples, railway stations, bus stops, and so on. It is more effective in urban places, which are typically congested. Although these systems produce less current or energy than other techniques, the advantage is that they do not require any form of fuel as an input. When compared to other approaches, this system's maintenance costs and component costs are lower. The concept of generating electrical energy via a non-traditional technique, simply by stepping in the footsteps, is expressed in [3].

The use of footsteps to generate energy requires no fuel. The fundamental concept is to generate power only via the use of a rack and pinion system in conjunction with an alternator. It turns Force into electrical energy for proper operation; the mechanism comprises of a rack and pinion, alternator, and battery. Power generation is important, although it has few early cost-effective elements. The technique by which pushing power is turned into electrical energy by suitable drive arrangement is described in [4]. The top plate holds the rack and pinion, spring arrangement. By releasing the load, the spring returns the plate to its original position. The smaller motor shaft is linked to the gear wheel. A permanent magnet D.C generator is employed in this application. Except for the pushing arrangement, the entire system is contained inside the floor level and is fitted in footsteps. The Rack and Pinion has the benefit of not requiring an external supply. In [5,] the working mechanism of the mechanical system is depicted, which is primarily reliant on an external force produced by a human being's footstep (walking person) on the top tile (power producing tile) and the potential energy that can be stored in the utilised spring.

The strolling individual, with a usual weight of roughly 75 kg, is intended to compress the employed linear springs. The footstep power producing tile model has dimensions of 70 cm x 70 cm x 13 cm. This tile is put on four springs with a 6 mm gap at each corner of the proposed system. [6] describes the appropriate administration and control of battery packs, which often contain numerous cells. Lead-acidbatteries, often known as lead storage batteries, can store a large amount of electrical charge and generate high current for short periods of time. The discharge of stored energy is dependent on both the positive and negative plates becoming lead sulphate and the electrolyte losing a significant amount of its dissolved sulphuric acid. The technology stores energy in the form of a 12V lead-acid battery.

The use of power producing speed breakers is explored in [7], such as how the design may be utilised to illuminate the streets by harnessing the jerking pressure that is lost when a car passes over a speed breaker on the roadside. We may harness the energy released by moving cars and use the speed breaker as a power generation device. The kinetic energy of moving cars is transferred to mechanical energy by a rack and pinion system, and this mechanical energy is transformed to electrical energy by a generator, which is used to power street lights.

As a result, by employing this technique, we may preserve a significant amount of energy that can be used to meet future demands. [8] provides an overview of the application of piezoelectric ceramic for energy production. The piezoelectric ceramic tile is not only a renewable energy source, but it is also one-of-a-kind, safe, dependable, geographically and economically. When the tiles are deployed in places where big crowds are expected, such as train stations, bus stops, airports, and shopping malls, and a person steps on them, the piezoelectric action builds a tiny charge on the surface of the crystals.

Though the energy provided by one person would be insufficient, as the number of steps on such tiles increased, so did the electrical charge produced. Electricity may be gathered by using electrodes. Such electricity can be stored in capacitors and distributed to power-deficient areas. [9] provides an explanation of the link between force, voltage, and slabs. In these slabs, the relationship between mechanical force and electrical voltage is proportionate. Human weight is used to apply the force. The more the weight applied, the greater the voltage created. The spring's strength determines the force strength. Springs absorb mechanical energy in their elasticity limit, according to Hook's Law. $F = -kx$ Where x is the spring's displacement from its normal length, F is the resultant force vector, the magnitude and direction of the spring's restoring force, and k is the spring constant, a constant that varies depending on the spring material and construction. [10] Describes the concept and methods of electrical power generation utilising footstep for urban area energy applications.

PROPOSED SYSTEM

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$F = -kx$ Where x is the spring's displacement from its normal length, F is the resultant force vector, the magnitude and direction of the spring's restoring force, and k is the spring constant, a constant that varies depending on the spring material and construction. [10] describes the concept and methods of electrical power generation utilising footstep for urban area energy applications. The rotating speed of the final shaft was engineered to match the rotational speed of the needed generator. As a result, a DC Gear Motor was utilised to create the power that was then stored in the energy storage system, which consisted of a sealed lead-acid battery. The energy generated by the motor is stored in a battery.

A boost converter boosts the voltage produced by the generator. This additional voltage is then sent to the inverter for conversion. As a result, the cycle of the individual maintaining Step on the generator tile, and the creation of power is repeated numerous times for this stored energy in the battery. The DC electricity is now transformed into AC for further usage by a DC-AC converter. That alternating current electricity is utilised to illuminate the LED bulb or is given at the needed load.

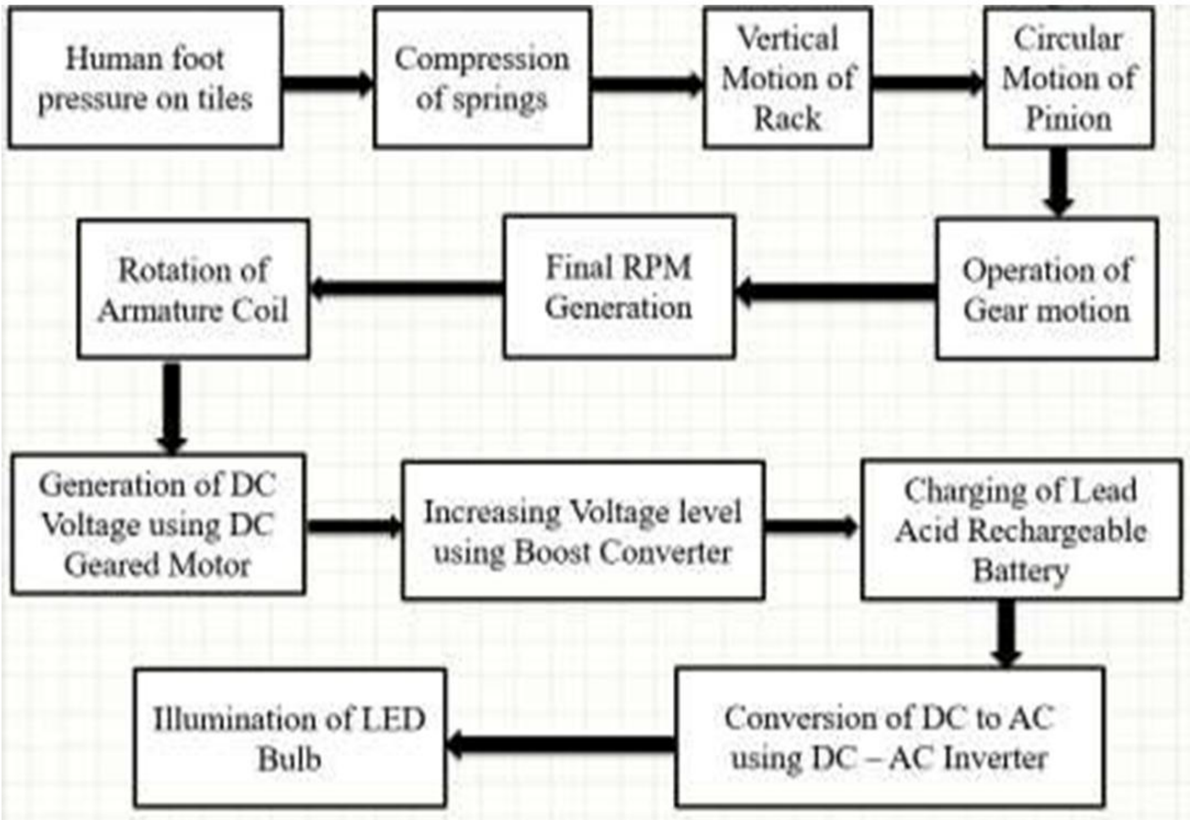

Fig. 1: Block diagram of the system.

Working Principle of Rack And Pinion

The primary fact on which this paper's operation is based is that the rack and pinion assembly turns linear motion into rotational motion and vice versa. The pinion has a limited diameter and produces circular motion when it comes into contact with the rack, which produces linear or translator motion.

For optimal contact, both rack and pinion should have equal modules. During motion, the shafts of the rack and pinion stay parallel. The pinion shaft is mechanically linked to the generator. As a result, the generator produces power.

When the spring expands, releasing the energy contained inside it, the rack rises vertically upward and comes into contact with the pinion. As a result, the pinion turns clockwise. The pinion shaft is mechanically linked to the generator.

As a result, the generator creates power once again.

DESIGN AND DEVELOPMENT OF THE SYSTEM

Mathematical Design

Let us consider the parameter and values given in the table:-

Table 1: Parameter and value.

Parameter	Notation	Value withunit
Mass of averageperson	m	70 kg
Acceleration due togravity	g	9.81 m/s^2
Height of spring	d	8 cm
Time	t	60 sec
Force	F	-
Work done	W	-
Output Power	P	-

From this, the force can be calculated as $= mg = 70 \times 9.81 = 686\ N$. Then, using the height of the spring the work done in one step is calculated as $= F \times d = 686 \times 0.08 = 54.88\ Nm$.

The output power can be estimated using the work done and time as $P = W/t = 54.88/60 = 0.91\ W$ so the power generated by one footstep or compression is estimated to be 0.91 W. Assuming, the continuous traffic of people on the floor, one can calculate the power generation for an hour as follows $= 0.91 \times 3600 = 3.27\ kW$ and thereby for a day power generation $= 78.48\ kW$ Considering the case of a college campus, its working time is for 8 hours and the Maximum traffic of students is between 9:30 to 10:30 am, 12:00 to 1:00 pm, and then 4:30 to 5:30 pm. So for these 3 hours, the calculation for power generation is as $= 3.27 \times 3 = 9.81\ kW$. These calculations purely depend upon the traffic of people.

Hardware Development

The developed hardware is covered in this section. This offers a sense of the entire system of power generation tiles:
A suitable selection of components creates the experimental arrangement. Two gears make up the rack and pinion gears system. The pinion gear is a standard round gear, while the rack is a straight or flat gear.

These are installed beneath the base plate. Spring connections are made between the base plate and the top plate. The system's performance is primarily determined by a number of compressions. A coil spring, also known as a helical spring, is a mechanical device that stores energy before releasing it, absorbs shock, or maintains a force between contacting surfaces. The weight of a human also plays an essential part in the generating of power, as the spring becomes more compressed as the weight increases. The DC motor is linked to the pinion. It rotates at 60 rpm, and 12V geared motors are typically basic DC motors with a gearbox connected.

This gear motor adds mechanical gears to the motor to change its speed/torque for a specific purpose. The number of rotations per minute determines the output of the DC generator. The produced electricity is stored in a lead-acid battery after compression. And the inverter is utilised to convert the DC input to the AC amplified output.

Fig. 2: Prototype top view

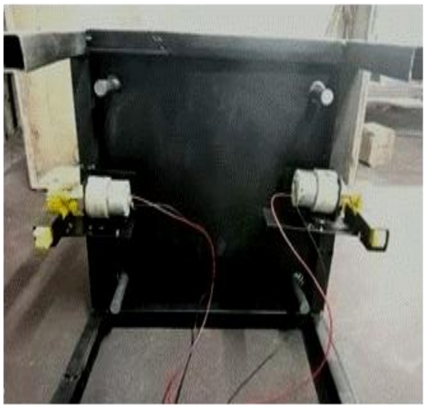

Fig. 3: Prototype bottom view (Motor Connections).

Practical Calculations

Table 2: Output values for different weights

Weight	DC Generator Volt	Boost Converter	Current of bulb	Practical Calculation
55kg	1.60 V	8.50 V	66.25 mA	0.71 W
60kg	2.25 V	9.9 V	67.2 mA	0.78 W
65kg	2.85 V	10.34 V	68.6 mA	0.85W
70kg	3 V	11.25 V	69.1 mA	0.91 W
75kg	3.5 V	12V	70.4mA	0. 98W

As can be seen, the real output is lower than the theoretical output due to several mechanical losses. Additionally, the overall efficiency of the system is lower; hence the system's output power is lower.

CONCLUSION

The introduction of the paper is described in this work on electricity generating tiles, covering the motivation behind the issue as well as the scope and purpose for the same. Because there is no need for electricity from the mains and there is no pollution in this source of energy, the system receives its energy requirements from a non-renewable source of energy. Several issues were discovered.

The report is made up of theoretical calculations that provide a general concept of output power generation. The component specifications and ratings are supplied, which is essential for hardware development. Each component's detailed operation

The suggested system's component is explained. This system's pros and downsides are examined. The module has various restrictions that may impair its efficiency, which are explained in the study, and their solutions are also considered. If the mechanical arrangement, such as the rack and pinion, becomes wet during the rainy season, the mechanical portion may corrode, reducing overall efficiency.

One benefit over the previous model, such as the piezoelectric crystal system, is that when damage happens, the piezoelectric crystal must be totally replaced, whereas the rack and pinion system may be fixed because the setup is mechanically manufactured. The structure and design of the power production setup can aid in the development of future applications by installing the same arrangement in schools, walkways, and congested locations.

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