

Design and Development of Power Generating Tiles and Demonstration

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ABSTRACT

In this paper, rack and pinion assembly is used for generating power by utilization of force which is obtained during the walking on steps. It generates electrical energy with the help of mechanical systems. The generated power is stored using a battery and this is used for activating the connected lighting loads. This is one of the compact and efficient systems for generating electricity that can be easily installed in many regions. The basic working principle is based on the spring force that is used to convert mechanical energy into electrical energy. This electrical energy is stored in the rechargeable battery connected to the inverter. Further, this inverter is used to convert dc to ac. This idea promotes non-conventional energy sources by generating electricity through human footsteps. The complete mathematical calculations and design are discussed in this paper. Further, its hardware model is developed to verify the mathematical design.

Keywords: Battery, electricity generation, generator, inverter, rack, and pinion

INTRODUCTION

Proposal for the utilization of waste energy of foot power with human locomotion is very much relevant and important for highly populated countries, like India where mobility of its masses can turn into a boon in generating electricity from its footsteps. In India, places like roads, railway stations, and bus stands, are all overcrowded and millions of people move round the clock. As a result, a large amount of power can be obtained with the use of this promising technology. This process involves several simple setups that are installed under the walking platform. When people walk on this platform their body weight compresses the setup which rotates a generator and the current produced is stored in the battery.

Greater movement of people will generate more energy. The motivation behind this design is that the non-conventional energy system is very essential at this time to our

nation and should be used. Non-conventional energy using footsteps needs no fuel input power to generate the electrical power. In this system, the simple drive mechanism i.e., rack and pinion assembly is used for generating power by utilization of force, which is obtained during the walking on steps. The power generation is much worthy but it has little initial cost-effective factors. The objectives of the work are listed below:

1. To generate the electricity through the human foot.
2. To promote the non-conventional energy source.
3. To store the electricity for further use.
4. To produce electricity at the cheapest cost.

LITERATURE SURVEY

In [1], the demand and importance of electricity are discussed. Energy is the main concern of the present day. There are different methods used for the

production of energy like conventional and non-conventional methods. In [2], various applications of mechanical foot step power generation are discussed, such as at colleges, temples, railway stations, bus stands, etc. In metropolitan cities, it is more useful as those cities are mostly overcrowded. Though compared to the other technique, less current or energy can be produced by these types of systems, but the advantage is that it would not require any kind of fuel as an input. The maintenance cost for this system and the cost of components of this design are less compared to other techniques. In [3], the idea of the generation of electrical energy using a non-conventional method just by walking in the footsteps is stated. Energy generation using footsteps requires no fuel input. Generating electricity just with the help of rack and pinion arrangement along with the alternator is the main idea. For its proper functioning, it converts Force into electrical energy, the mechanism consists of a rack and pinion, alternator, and battery. The power generation is much worthy but it has little initial cost-effective factors. In [4], the mechanism by which the pushing power is converted into electrical energy by proper driving arrangement is explained. The rack and pinion, spring arrangement is fixed at the upper plate. The spring is used to return the plate to the same position by releasing the load. The gear wheel is coupled to the smaller motor shaft. The generator used here is a permanent magnet D.C generator. This arrangement is fitted in footsteps the complete arrangement is kept inside the floor level except for the pushing arrangement. The Rack and Pinion have the advantage that it does not utilize any external source. In [5], the working mechanism of the mechanical system which mainly relies on an external force

is demonstrated that can be supplied by a human being's footstep (walking person) on the top tile (power generating tile) and the potential energy that can be stored in the used spring. It is expected that the walking person, who has a normal weight of about 75 kg, could compress the used linear springs. The model design of the footstep power generating tile has a dimension of 70 cm x 70 cm x 13 cm. This tile is laid on four springs positioned at each corner of the designed system with a gap of 6 mm. In [6], an explanation of the proper management and control of battery packs is described, which usually comprise many cells. The battery which we are using is Lead-acid batteries, also known as lead storage batteries, which can store a lot of electrical charges and provide high current for short periods. Discharging the stored energy relies on both the positive and negative plates becoming lead sulfate and the electrolyte losing much of its dissolved sulphuric acid. The system uses a 12V lead-acid battery for storing energy. In [7], the application of power generating speed breakers is discussed like the design can be used to enlighten the streets utilizing the jerking pressure which is wasted during the vehicles passes over speed breaker on the roadside. We can tap the energy generated by moving vehicles and produce power by using the speed breaker as a power generating unit. The kinetic energy of the moving vehicles can be converted into mechanical energy through a rack and pinion mechanism and this mechanical energy is converted to electrical energy using a generator which is used for lighting the street lights. Therefore, by using this mechanism we can save a lot of energy which can fulfill future needs. In [8], an overview of the use of piezoelectric ceramic for the generation of electricity

is given. The piezoelectric ceramic tile is not only a renewable electricity source but also unique, safe, reliable, geographically, and economically. When the tiles are installed in locations where large crowd movements are expected, like in the railway, bus stations, airports, and malls, and a person steps on them, then by the piezoelectric effect, a small charge is built upon the surface of crystals. Though energy generated by one person would be too little if the number of steps on such tiles increases then the electrical charge produced by it would increase too. The electricity can be collected by the use of electrodes. Such electricity can be stored in capacitors and power can be channeled to electricity deficient regions. In [9], an explanation of the relationship between force, voltage, and slabs is stated. The relation between mechanical force and electrical voltage is proportional in these slabs. The force is applied in the form of human weight. The more the weight is applied, the more the voltage is generated. The force strength is depended on the spring's strength. Springs consume the mechanical energy obeying Hook's Law in their elasticity limit $F = -kx$ Where x is the displacement of springs from its normal length, F is the resulting force vector, the magnitude and direction of the restoring force the spring exerts, k is the spring constant, a constant that depends on the spring material and construction. In [10], the design and methodology of electrical power generation using footstep for urban area energy applications are explained.

PROPOSED SYSTEM

The spring and rack & pinion arrangements are fixed below the footstep which is mounted on the base. A rack and pinion is a type of linear actuator that comprises a pair of gears. A spring system

is used for the return mechanism of the upper plate after the release of load. When force is applied to the plate by stamping on the plate the force spring gets compressed as a result the rack moves vertically down. The downward linear movement of the power generating tile could compress the system's rack and springs with a small amount of mechanical losses. When the rack moves downward as human weight is applied, it causes rotation of the pinion. The pinion is meshed with the rack gear which results in the circular motion of the pinion gear. A single gear and pinion are meshed with a sliding toothed rank. This combination converts the rotary motion into the back and forth motion. Once the footstep is removed from the tile, the potential energy stored by the springs is used to push the tile back to its original position. For one full compression, the pinion moves one semicircle, when the force applied on the plate is released the pinion reverses and moves another semicircle. Hence, there is the generation of RPM. The intermediate gear with a greater number of teeth rotates as a result of the motion of the pinion. The shaft of the DC gear motor is connected to the last gear meshed with pinion. DC gear motor attached to the intermediate obtains the rotating motion, hence resulting in the sinusoidal waveform.

The rotational speed of the final shaft was designed to be matched with the required generator's rotational speed. Hence, DC Gear Motor was used to generate the power that was stored in the adopted energy storage system which comprises a sealed lead-acid battery. A battery is used to store the energy generated from the motor. The voltage produced by the generator is increased using a boost converter. This increased voltage is then sent to the inverter for the conversion process. Thus, the cycle of the person keeping

footstep on the generator tile and generation of electricity is continued several times for this stored energy in the battery in a proper way. Now for further use, the DC power is converted

into AC by using DC- AC inverter. That AC power is used to illuminate the LED bulb or delivered at the required load.

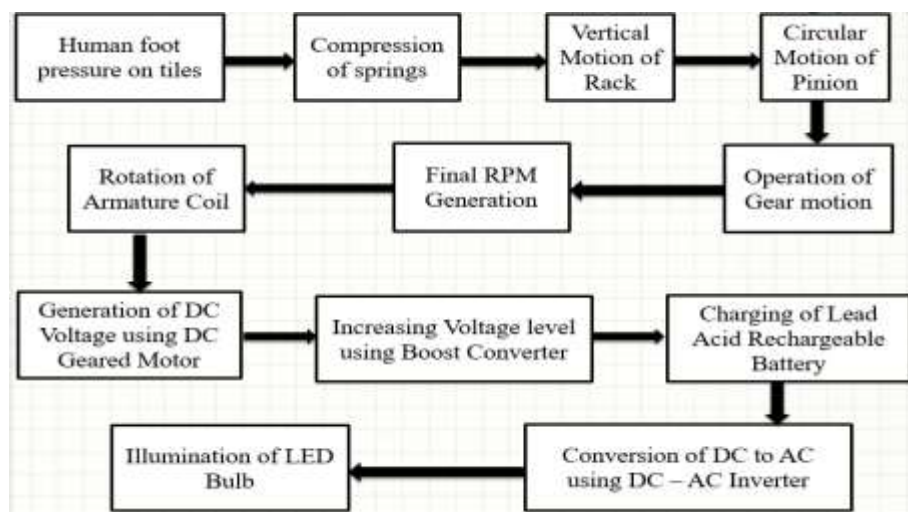


Fig. 1: Block diagram of the system.

WORKING PRINCIPLE OF RACK AND PINION

The main phenomenon on which the working of this paper is based is that rack and pinion assemble converts the linear motion into rotary motion and vice versa also. The pinion is of finite diameter and gives circular motion when the rack of infinite diameter comes in contact with the pinion and gives linear or translator motion for proper contact between both rack and pinion, they should have equal

modules. The shafts of the rack and pinion remain parallel during their motion. The pinion shaft is directly coupled with the generator. So, the generator generates electricity. When the spring expands releasing the energy stored inside it, the rack moves in an upward direction vertically and the rack is in contact with the pinion. So, the pinion rotates in the clockwise direction. The pinion shaft is directly coupled with the generator. So, the generator generates electricity 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 with unit
Mass of average person	m	70 kg
Acceleration due to gravity	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 $F = mg = 70 \times 9.81 = 686 \text{ N}$. Then, using the height of the spring the work done in one step is calculated as $W = F \times d = 686 \times 0.08 = 54.88 \text{ Nm}$.

The output power can be estimated using the work done and time as $P = W/t = 54.88/60 = 0.91 \text{ W}$ 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 $= 0.91 \times 3600 = 3.27 \text{ kW}$ and thereby for a day power generation $= 78.48 \text{ kW}$

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 $= 3.27 \times 3 = 9.81 \text{ kW}$. These calculations purely depend upon the traffic of people.

Hardware Development

In this section, the developed hardware is discussed. This gives the idea about the whole system of power generating tiles:

The experimental setup is developed by an appropriate selection of components.

The rack and pinion gears system is composed of two gears. The normal round gear is the pinion gear and the straight or flat gear is the rack.

These are mounted below the base plate. In between the base plate and upper plate, springs are connected. The performance of the system mainly depends upon a number of compressions. A coil spring, also known as a helical spring, is a mechanical device that is typically used to store energy and subsequently release it, absorb shock, or maintain a force between contacting surfaces.

The weight of a person also plays an important role in the generation of power as spring gets more compressed for greater weight. The pinion is connected to the DC motor. It is 60 rpm and 12V geared motors are generally simple DC motors with a gearbox attached to it.

This gear motor adds mechanical gears to alter the speed/torque of the motor for an application. The output of the DC generator is determined by the number of revolutions per minute. After compression, the generated electric power is stored in the lead-acid battery. And the inverter is used for the conversion of DC input to 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 clearly observed the practical output is less as compared to theoretical output it is because there are many mechanical losses also the overall efficiency of the system is less hence the output power of the system is less.

CONCLUSION

In this work of power generating tiles, the introduction of the paper is discussed, including the motivation behind the topic and scope and objective for the same. The system gets its energy requirements from the Non-renewable source of energy as there is no need for power from the mains and there is no pollution in this source of energy. Several problems were identified.

The report consists of theoretical calculations which give a brief idea about output power generation. Specifications of the components along with their ratings are included, which is required for the hardware development. The detailed working of each

component of the proposed system is explained. The advantages, as well as disadvantages of this system, are discussed. The module has some limitations which may affect its efficiency are described in the report along with that its solution is also discussed. In the rainy season, if the mechanical arrangement like rack and pinion gets wet then the mechanical part may get rusted which may hamper overall efficiency.

One of the advantages over the previous model like the piezoelectric crystal system is that, here when damage occurs the piezoelectric crystal is to be completely replaced but the rack and pinion system can be repaired as the setup is built mechanically. The construction and design of the power generation setup can help to make future applications by fixing the same arrangement at schools, footpaths, and overcrowded areas.

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