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Harvesting Energy Through Rotation of Doors

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ABSTRACT

This paper deals with the designing, manufacturing, and working of a mechanical-electrical device that will convert the rotational energy produced by doors to electrical energy. This device will use a planetary gear system, generator, batteries, and other electrical appliances. This device will not only convert the rotational energy into electrical energy but can also store the generated electrical energy to be appropriately used.

Keywords— *Batteries, Electricity, Gear train, Generator, Regenerative energy, Rotational energy*

1. INTRODUCTION

As the population on earth is exponentially increasing, nonrenewable resources of energy are getting depleted at an alarming rate. These resources take a long period to generate but are getting exhausted very quickly. Everyone is now turning towards renewable energy sources to procure energy such as solar energy, wind energy, hydro energy, etc. Among these renewable energy sources, there is rotational energy which is inexhaustible. Every time anything moves in a circular path, rotational energy is generated. We are proposing a device that uses rotational energy to produce electrical energy.

Every time a door is opened or closed; the mechanical energy required in doing so is converted into rotational energy. This mechanical energy practically gets wasted because the rotational energy is further put into no use. Our device will convert this rotational energy into electrical energy. This device will be attached to a door and every time a door is swung open the mechanical energy required to do so which gets converted into rotational energy will be converted to electrical energy which can further be used for numerous applications. Our device will use a planetary gear system for amplifying the produced rpm and a generator to produce electrical energy from this amplified rpm. This electrical energy will further be stored and later can be directed wherever required. The following device has been designed for residential as well as commercial purpose doors. More is the traffic using the door, more is the electrical energy produced. No significantly extra mechanical energy would be required to rotate such a door. Such a door will function like any other normal does without any extra friction or additional mechanical problems.

2. LITERATURE REVIEW

Royal Boon Edam has developed the NRG + Tourniket, an energy-generating revolving door, which is claimed to generate 10 W per passage to power the ceiling lamps in the door (Edam, 2015). It has been claimed that this saved 4,600 kWh/year of energy when installed in a railway station, however, there is no indication as to how much of this was a result of the energy that was actually generated through the use of the door (Edam, 2008).

ln (Ahmad, Mazli, & Ariffin, 2016) an energy generation system was developed that directly utilized the motion of a swing door through a gearing system and dynamo. It was found that this produced an 11.54 V output and was deemed sufficient to charge a phone battery.

In the work of (Hinge & Chaudhari, 2016) a generation unit has been developed to make use of the energy present from a user transiting through a swing door. This system uses the mass of the user on a plate installed on the floor to drive a dynamo through a rack and pinion system. This was found to produce in the range of 1.1–1.3 W during use.

A swing door generator utilizing an AC stepper motor with appropriate power conditioning was developed in the work of (Zylka & Pociecha, 2016). Experimental testing revealed that 12.7 mJ of electrical energy could be generated from a single door use, however, this reduced to 3mJ when the power conditioning was included.

In (Gilani et al., 2015) the energy generated from a single door use was found to be 15.67 J. In the work of (Mohurle, Deshmukh, & Patil, 2015) several human-powered energy harvesting devices were developed for use in a garden. Amongst these was a revolving door that utilized a gearing system to directly harness the motion of the door to drive a generator. It was found that the power output is proportional to the torque applied on the motor shaft, where a peak output of 48 W was achieved for an applied torque (on the motor) of 7.5 Nm.

In (Ahamed et al., 2016) the power output was found to be in the range of 1.564–2.6 W depending on the angular velocity of the door.

The literature has revealed considerable work on energy harvesting from door use. The main aim of this paper is to assess the potential for electrical energy generation that is offered by harvesting the mechanical work expended by people to operate swing or revolving doors.

3. METHODOLOGY

3.1 Materials

Materials used in this project:

- Epicyclic gear train.
- Sheet metal base of the contraption which houses the gear train and generator.
- Steel tubes to build a scaled replica of a simple revolving door mechanism, also facilitates the manufacturing of the shafts.
- Diodes and wires to build a circuit that neutralizes the change in polarity and direction of the generated current.

3.2 Working

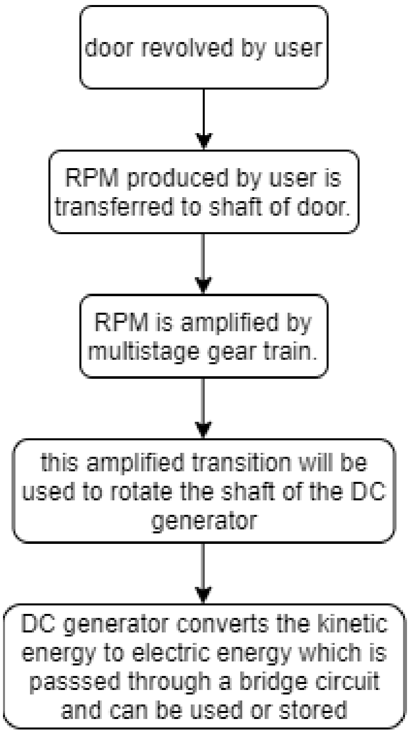

Fig 1. Flowchart

3.3 Design

3.3.1 Mechanical Design

When it comes to the mechanical implementation of the proposed prototype the system consists of 4 panels (doors) centrally connected to a shaft which is in turn connected to a multistage epicyclic gear train that amplifies the input rpm and provides the magnified rpm to a generator.

The following render is provided for better understanding:

Fig 2. final render of the prototype (glass package is only for representation)

The door panels are made of 18-16 steel pipes that are welded together to the central shaft. The center shaft is coupled with a disc, which will rest on the base with a thrust bearing in between. This will distribute the load of the pipe structure on the base of the structure. As is visible in fig 2. The gear train is connected to the dc generator which is placed above the housing for the electronic components.

3.3.2 Prototype dimensions

Table 1

Overall dimensions	360 x 360 x 747mm
Door panel width	180 mm
Door panel height	360 mm
Pipe dimensions	OD = 18mm ID = 16mm
Shaft length	400 mm
Container dimensions	300 x 300 x 334 mm

3.3.3. Gear Train

For our purpose, we have implemented a two-stage, multi-stage planetary gear train with a ratio of 1:4 the system consists of planetary gears attached to a carrier which acts as the input, a ring gear which is fixed and the sun gear which acts as the output. The sun gear rotates the output shaft to facilitate the rotation of the shaft of the generator which ultimately produces electricity.

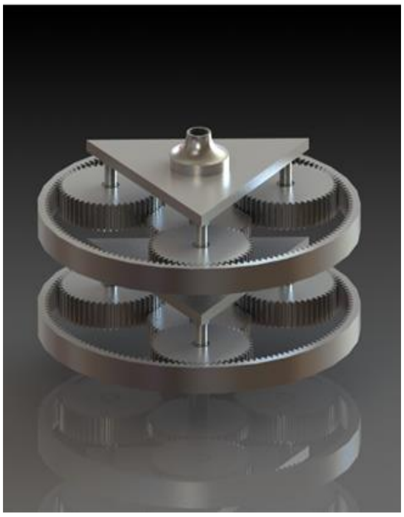

Fig 3. Two stage planetary gear train.

3.3.4 Calculations for the planetary gear system:

We have used the tabular method to calculate the ratio of teeth between the sun and ring gears.

Table 2

S	C	P	I
+x	0	$-x\left(\frac{Ts}{Tp}\right)$	$-x\left(\frac{Ts}{Tp}\right)\times\left(\frac{Tp}{Ti}\right)$
+x	0	$-x\left(\frac{Ts}{Tp}\right)$	$-x\left(\frac{Ts}{Ti}\right)$
+x	y+x	$y-x\left(\frac{Ts}{Tp}\right)$	$y-x\left(\frac{Ts}{Ti}\right)$

rpm I = 0 (fixed)

$$y - x\left(\frac{Ts}{Ti}\right) = 0, y = x\left(\frac{Ts}{Ti}\right)$$

$$\text{Torque ratio} = \frac{\text{Output } \tau}{\text{Input } \tau} = \frac{\text{Input rpm}}{\text{Output rpm}} = \frac{y+x}{y}$$

We have taken torque ratio as 4 therefore,

$$4 = \frac{y+x}{y} = \left[\frac{x\left(\frac{Ts}{Ti}\right)+1}{x\left(\frac{Ts}{Ti}\right)}\right]$$

$$4 = \frac{Ts}{Ti} \Rightarrow 4Ts = Ts + Ti$$

$$\Rightarrow \mathbf{3Ts = Ti}$$

Using this relation, we selected 50 teeth and 150 teeth for the sun and ring gear respectively. After considering the torque applied, power input we calculated the appropriate module for the gear system.

The specifications of the gears are as follows:

Table 3

Gear	PCD	No. of teeth	Module	design value	face width
Sun	68.75	50	1.361	1.375	16.5
Planet	68.75	50	1.361	1.375	16.5
Ring	206.25	150	1.361	1.375	16.5

3.3.5 Factors considered

Table 4

Power	0.1 kW
Input rpm	10
pressure angle	20
Sut	2100
fs	1.5
Lewis form factor	0.41
Velocity Factor	0.98814

Motion analysis for a single stage of the train was also carried out on SOLIDWORKS where the ring gear was constrained and input of 10 rpm was given to the shaft fixed to the carrier.

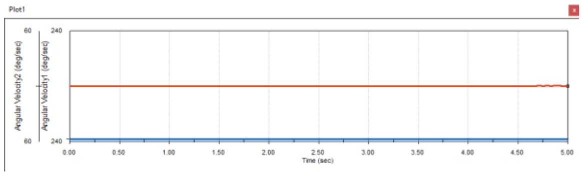

Fig 4. Analysis result

fig 4 is the superimposed plot of the angular velocities in degrees/sec of the input gear(red) and output gear(blue) which clearly shows that in the case of one stage we obtain a ratio of 1:4 which can be boosted to 1:16 by simply adding a second stage to the gearbox.

3.3.6 Electrical Design

For the prototype, a DC generator will be used. As per the specifications given by the dealer, the motor output voltage is in the range of 5v-24v. The faster the speed of rotation, the higher the output. The maximum load voltage is 40 v. Maximum output current exceeds 2000mA. The power output given is 20W. A LED bulb of ratings DC 12V-9W will be attached to the end of the voltage regulator (LM 317) or DC-DC booster. This will ensure that the power will be transmitted only when the output from the generator is between 12v to 24v.

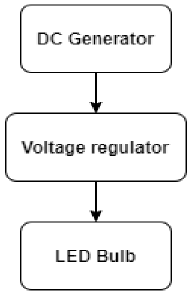

Fig 5. Power circuit flow

Whenever the door rotates at 5-7 rpm, the generator receives an input in the range of 80-100 rpm. It will then give an output of 12v-24v at 20W. Then after going through the booster, a constant voltage of 12v will be obtained. Hence, the bulb will glow for whatever duration the generator is giving the output.

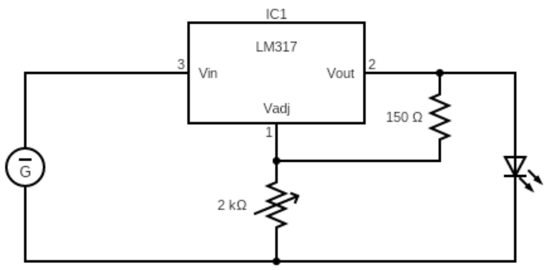

Fig 6. Circuit diagram for powering a bulb.

The same circuit with minor modifications can be used for the charging of batteries as well. Configuring the booster to give an output of 5V/12V - 4A/1.7A - will help in charging the small batteries or lead-acid batteries (used in bikes or inverter batteries). This will be a slow process though, as the current is low.

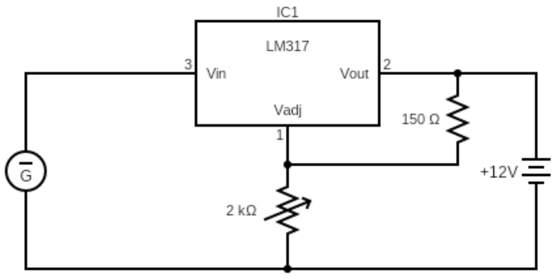

Fig 7. Circuit for charging a 12v battery

The charging of multiple batteries can be automated if BMS is used.

4. RESULTS AND DISCUSSIONS

The final output is a systematically functioning mechanical-electrical device that converts rotational energy produced by doors into electrical energy. The above proposed design and methodology was successfully implemented and has resulted in the said device. Amplification of the produced rpm and efficient conversion of this amplified mechanical energy was successfully attained. This device can be installed on any door and can be used to acquire renewable electrical energy predominantly for domestic use. The energy produced can successfully be directed towards any external input required. The proposed device can produce approximately 20.075 Kilowatts of energy in one year. For doors with commercial use, with more powerful motors, approximately 2.5-3 kW of energy can be produced per day. This means, by installing this device on any one door for one year, we can light one tube light for approximately 830 days, considering the consumption of one tube light to be 55 Watts/hour. The more the number of doors and the more the locomotion flux through these doors, the more is the amount of electrical energy produced.

Coming to the large-scale implementation of this project, the gear ratios will change based on the minimum rpm required by the generator. Usually in malls or complexes, where the energy required is high, a generator of 1kW can be used. The generated energy can be sent to the power stations nearby. This process is similar to building mini solar power generators on roofs. Certain requirements are to be fulfilled if the power is to be sent to power stations nearby. By changing the generators, rpm and having multiple sources of generation can help in meeting up with the criteria of the power stations.

The energy harvested through these systems can also be stored in batteries locally for back-ups in malls or complexes. When it comes to power management, the backup power source is used only for emergency services in case of power failure. The output current from generators can be boosted to charge the batteries faster. This will help in reducing costs by 10% annually.

The following device is very easy to install and requires minimal maintenance. Thus, this device provides an inexhaustible source of electrical energy for everyone. No considerably extra effort would be required by the user to operate a door equipped with such a device.

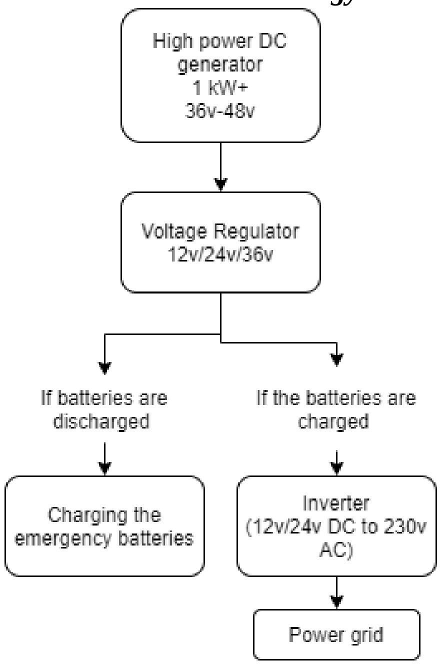

Fig 8. Large Scale implementation of this project

5. LIMITATIONS

Although this device is a viable solution for producing renewable electricity, there are a few limitations to this method. This method requires a high investment initially with periodic maintenance of gears and mechanical systems. The generated energy may not seem significant over a short period of time, but this will help in reducing the operational costs over time. Commercial use of this method is a bit difficult as installing this device on all the pre-installed doors might be a tedious task. Now, humans are moving towards renewable energy sources so this model can be implemented easily during the construction of new complexes.

6. FUTURE SCOPE

The proposed electrical device has plenty of room for improvement as well as scope for future applications. There are hundreds of thousands of playgrounds in the world with multiple mechanical merry-go-rounds each. If we could implement this same design to use rotational energy produced by these merry-go-rounds to produce electrical energy, a considerable amount of electricity could be produced. This will be an inexhaustible source of electricity that would never run its course. The same working principle of this device could be extrapolated to design and manufacture a device for mechanical merry-go-rounds. We could alter the electrical components used to maximize the production of electricity and the efficiency of the said device. We could also experiment with different gear ratios and find the most optimum ratio for each respective application.

7. CONCLUSION

In today's changing modern world, the use of nonrenewable energy resources has become the need of the hour. This device not only fulfills this ever increasingly important need but is also creating a sense of responsibility among the citizens. It is creating a sense of understanding and maturity among the society that the use of inexhaustible energy resources must be increased and is inevitable. In conclusion, the proposed mechanical-electrical device will convert the mechanical energy which is used to rotate a door into electrical energy. This device is a sincere effort towards promoting the use of nonrenewable resources, reducing the use of exhaustible resources to produce energy, thus saving the environment.

8. ACKNOWLEDGMENT

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