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DEVELOPMENT OF ENERGY HARVESTING SYSTEM USING ROTATION MECHANISM OF A REVOLVING DOOR

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ABSTRACT

Conventional energy sources are depleting with time. There is a dire need to find new sources of energy. The new sources of energy should be able to replace dwindling sources of energy. Energy Harvesting is one such method where ambient energy from environment is converted into useful energy. The purpose of this study is to show that the ambient energy in the surroundings can be utilized to generate electricity. In this project, the energy used to open a revolving door is being converted into electrical energy. Accordingly, a revolving door prototype is designed, fabricated and tested. The test results show that 15.67 Joules can be produced from one push of the door. A carbon comparison case study is carried out based on the results. This prototype can be further optimized in terms of size to generate more electrical energy.

Keywords: harvesting system, rotation mechanism, energy.

INTRODUCTION

The concept of Energy harvesting is to avail the energy that is usually available in the surroundings and convert it into useful electrical energy [1]. Most people do not realize that there is a lot of energy that is formed around them all the time. Energy can be harvested from various sources such as vibrations, thermal and mechanical sources, etc. [2]. Currently, the energy harvesting makes little impact on the overall electricity consumption in a built environment. However, it does improve the overall consumption by a little margin and in the future; this margin will be magnified by the production and implementation of more and more energy harvesting products in the market [3].

The idea of using revolving doors to harness Energy is relatively new in the market. This green energy solution makes use of an everyday occurrence to produce some electrical energy can be used for large range of lowpoweredelectronics [4]. Currently, research is being done on methods to improve the efficiency of the revolving door to obtain maximum output power. Although it is agreed that this method is not a major source of power production, it is definitely a step forward in the direction of renewable energy.

Energy harvesting revolving doors

The basic mechanism of a revolving door typically consists of a centre shaft with three to four door panels hanging on it. The shaft rotates around a vertical axis within a round enclosure. The main purpose of revolving door is to reduce the heating or cooling required for the building.

Harnessing energy from revolving doors will not impact the force applied by the user. It is because the currently used revolving doors are also applied with gearing and highly viscous fluid which dampens their spin. Kinetic energy is dissipated in these systems so the door spins within a relatively predictable range of speeds. The difference in this concept is that it would replace the existing mechanisms (fluid or gears) with the internal resistance of a generator. So the energy transferred by people into the door isn't dissipated. Rather, it is captured and converted into useful electrical energy.

A revolving door designed and fabricated by Fluxxlab stands on a platform by the entrance [5]. The door harnesses the energy created by the movement of the door when visitors walk through it. The harvested energy is utilized to power a sign that lights up as people pass through. The energy harvesting revolving doors are placed at a number of places in New York for the purpose of exhibition, each one a potential source of untapped energy. The design by the author in [4] is rather simple and the purpose of the research is to find the effect of torque on the output power. A simple prototype was fabricated in order to carry out the experimentations. With the rotation of door, the motion of shaft is converted into sufficient speed by a pair of gears for producing electricity through generator. The output voltage is regulated at a certain level and used to analyse the effect of torque by varying the panel length and applied force. The author also proposed to install a power management circuit and battery to store the energy produced by the door. The model consists of a revolving door, a gear reduction system, and a generator.

Design and fabrication

Before starting the design of the prototype, it should be decided whether the door needs to have three panels or four panels. For a user to enter from one side and exit from another for a four panel door, the door needs to be rotated at least 180 degrees. As in the case of three

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panel door, the user needs to rotate the door at least 120 degrees to enter from one side and exit from the other. Theoretically, more rotation gives us more torque in the shaft. Therefore, the design of the revolving door is chosen to be four panel. The rotation comparison between three and four panel design is depicted in Figure-1.

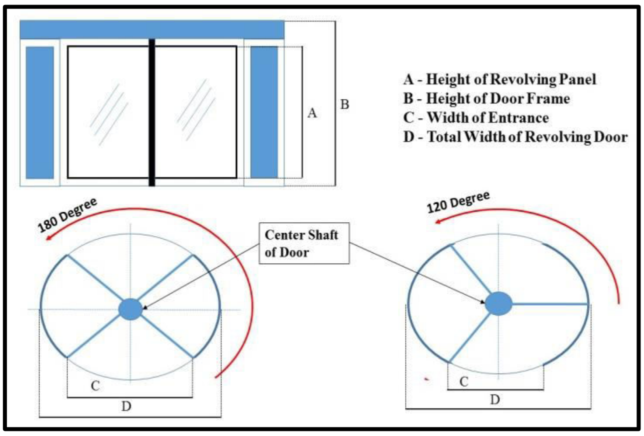

Figure-1. Rotation comparison between three and four panel design.

Design of the prototype

The design of the prototype was made using AutoCAD and is depicted in Figure-2. The material of the outer frame of the prototype is chosen to be hollow steel and the material for the revolving door is chosen to be Perspex with thickness 3mm. The purpose for material selection is to ensure that the frame is able to support the door by making the door lighter than the frame. Another reason for the material selection is the availability of the material itself. The compartment below the revolving door is designed as housing for the gear mesh and the generator.

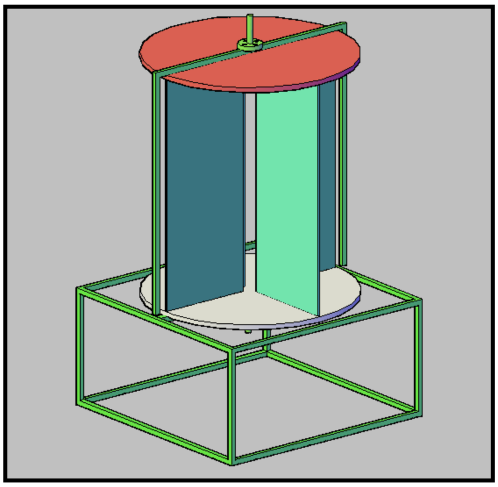

Figure-2. 3D model of the revolving door.

Fabrication of the prototype

The prototype was completed successfully under supervision of the technicians. Firstly, hollow steel bars were cut into appropriate sizes. The steel bars were welded into position to form the frame of the prototype. Secondly, the Perspex were cut into sheets that consisted of the door panels and the upper and lower support for the door. The panels and both upper and lower support were fastened to each other using steel rivets. Then, the door was mounted onto the steel frame. Lastly, the gear and generator were placed accordingly in the housing under the door frame. It was also ensured that the door and gears are properly aligned before the door was rotated. The final product can be seen in Figure-3 and Figure-4.

Figure-3. Side view of the prototype.

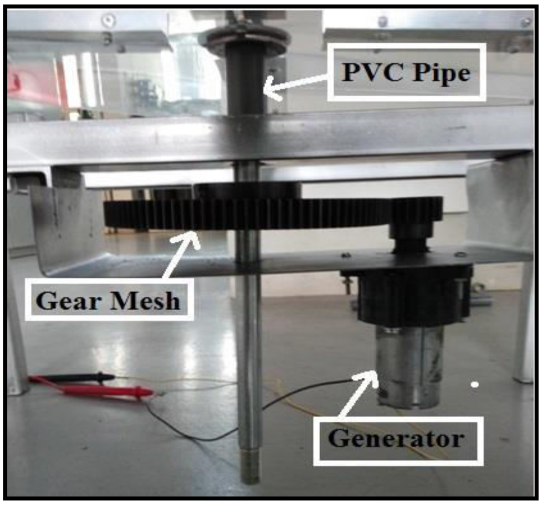

Figure-4. Close insight view of the gears and generator at the bottom of the prototype.

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The selection of the generator and gear were very important attributes of the project. It is because, the size of the gear and the specifications of the generator directly determine the output voltage of the prototype. The generator has a built in gear reduction mechanism apart from the reduction provided by the steel spur gears. This further helps in generating higher power output. Table-1 and Table-2 show the specifications of generator and gears used in the project.

Table-1. General specifications of generator.

Output Voltage	5V- 24V
Output Current	1500 mA
Speed	120 RPM
Max load : 20 watts	20 watts
Weight	490g

Table-2. General specifications of the gears.

	Driver gear	**Driven gear**
Material	Steel	Steel
No. of Teeth	100	20
Ratio	5	1
Bore Diameter (mm)	15	8
Hub Diameter (mm)	60	24
Pitch Diameter (mm)	150	30
Outside Diameter (mm)	153	33

RESULTS AND DISCUSSIONS

The testing procedure included ‘PASCO 850 UNIVERSAL INTERFACE’ device and ‘PASCO Capstone’ software to record the output voltage and output current. The PASCO 850 Universal Interface is a USB (Universal Serial Bus) multi-port data acquisition interface designed for use with any PASCO sensor and PASCO Capstone software (available separately) [6]. Users are able to plug a sensor into one of the twelve input ports on the interface, perform setup in the PASCO Capstone program, and then begin collecting data. PASCO Capstone software records, displays and analyses the data measured by the sensor. Figure-5 shows the interface device.

Figure-5. PASCO 850 universal interface devices.

The significance of using PASCO for output recording is its greater accuracy over a Multi-meter. PASCO records data against time for shorter intervals as compared to a multi-meter. It also has the capability to export the data for further analysis. Therefore, PASCO is selected for testing.

Three simulations were conducted to obtain the results for both output voltage and output current when the door is pushed. From the experience conducting the simulations, it is found that it is optimum to have multiple simulations considering the time taken to complete the simulations. Thus, the accuracy of the result was increased. The PASCO generated results in tabular form. The results we rearranged in Microsoft Excel and the graphs were plotted accordingly. Average voltage and average current was derived from the three simulations. The output power was then derived from the simulations as a product of both voltage and current.

The average voltage and current through time from the three simulations are shown in Figure-6 and Figure-7 respectively. In Figure-8, the average output power is derived as a product of average output voltage and average output current when the door is pushed once. It can be noticed that the peak power is 10.86 watt per push. The energy generated per push can be calculated from the graph in Figure-9. It is represented by the area under the curve.

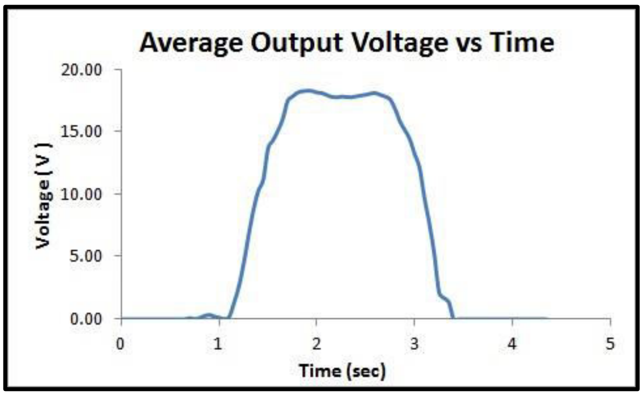

Figure-6. Average output voltage vs time.

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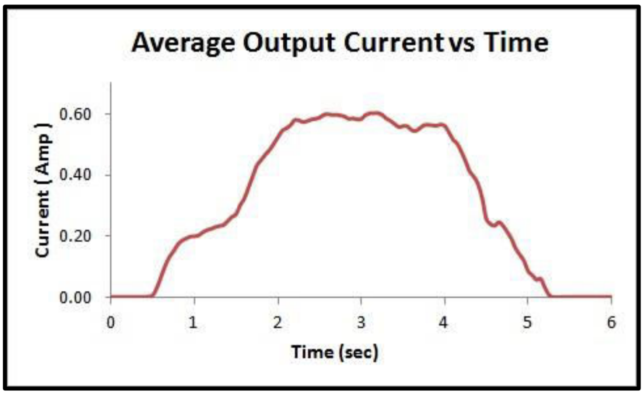

Figure-7. Average output current vs time.

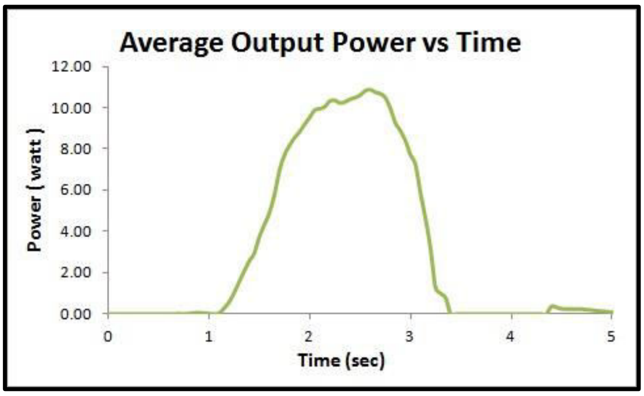

Figure-8. Average output power vs time.

Equation 1 represents the average output power and is of quadratic nature. It is extracted from the results using Microsoft Excel and will assist in calculation of energy generated per push. The trend line is set to be a sixth order polynomial for increased accuracy in the approximation.

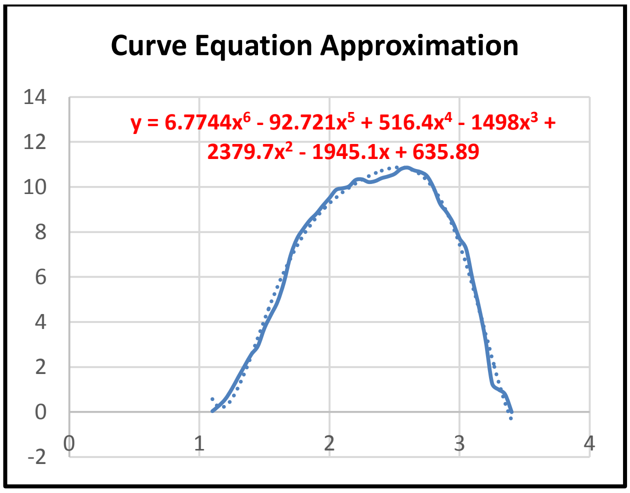

Figure-9. Curve equation approximation using 6^{th} order polynomial.

$$y = 6.7744x^6 - 92.721x^5 + 516.4x^4 - 1498x^3 + 2379.7x^2 - 1945.1\,x + 635.89 \quad (1)$$

The X – Intercepts are '1.1' and '3.4'. Therefore, energy generated per push is an integration of Equation 1from point '1.1' to point '3.4'.

$$Energy = \int_{1.1}^{3.4} 6.7744x^6 - 92.721x^5 + 516.4x^4 - 1498x^3 + 2379.7x^2 - 1945.1\,x + 635.89 \;\; dx \quad (2)$$

$$\therefore\ Energy\ generated\ per\ push = 15.91\ Joules$$

From the calculations, it can be noted that the energy generated per push is 15.91 Joules. It is sufficient output energy and can be further optimized by using a higher gear reduction ratio and a generator with higher efficiency. It should also be noted that this energy is generated using a small scale model. Therefore, a full scale model of a revolving door will definitely account for higher power output. In the following section, a case study is performed based on the prototype output energy data.

Case study for implementation

It was found that the shopping mall '1 Utama' is Malaysia's largest shopping mall and the fourth largest shopping mall in the world. The average number of people entering the mall during a weekday is between 60000 to 90000. The average number of people on a weekend is 120000 [7].

The mall operates from 10 am to 10 pm. Therefore, the door can be used for 12 hours. The average time to open the door is 2 seconds. It is noted that the door can rotate a maximum of 38000 times in a day.

Total Energy produced in a day

$$= (38000)(15.91\ \text{Joules})$$

$$Total\ energy\ per\ day = 604580\ Joules$$

$$Kilowatt\ Hour = (604580\ Joules/3.6\ \times 10^6 Joules)$$

$$Kilowatt\ Hour = 0.168\ kWh$$

$$Energy\ produced\ yearly = 0.168\ kWh\ \times 365\ days$$

$$= 61.29\ kWh/year$$

The purpose of these calculations is to show the contribution of this project to the environment by saving coal and releasing less Carbon Dioxide to the environment.

1 kg of coal produces 2 kWh and by burning 1 kg of coal, 2.93 kg of Carbon Dioxide is released into the environment [8].

$$Coal\ saved\ per\ year = \frac{61.29\ kWh}{2\ kWh} = 30.649\ kg$$

$$CO_2\ saved\ from\ being\ released\ into\ environment = 30.649 \times 2.93kg$$
$$= 89.80\ kg$$

Therefore, with the implementation of the door in a busy shopping mall as '1 Utama', the power produced per year can account for saving 88.23 kg of CO2 being emitted into the environment each year.

CONCLUSIONS

The test results of the final prototype design shows that 15.91 joules of energy can be harvested from one push of the door. This results in 61.29 kWh on an annual basis assuming the door is implemented in a busy shopping mall. According to the case study implementation, 89.80 kg of CO2 emissions can be omitted on a yearly basis. This proves that the Revolving Door has enough potential to produce sufficient energy and it should be implemented in busy public places to have an interactive alternative source of clean energy.

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