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

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

May 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

SYED FAIZAN UL HAQ GILANI
13965
ELECTRICAL AND ELECTRONIC ENGINEERING

ABSTRACT

Conventional Energy sources are depleting with time. There is a dire need to find new sources of energy. The new methods 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. Unfortunately, there is not enough work done on energy harvesters. The purpose of this project is to show that the abundant 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 was designed, fabricated and tested. The test results are used to calculate the amount of energy being harvested on one push of the door. This prototype can be further optimized in order to generate more Electrical Energy.

ACKNOWLEDGEMENT

First and foremost, I would like to thank Allah (S.W.T) for endowing me with health, patience, and knowledge to complete this work. Next I would like to use this opportunity to thank several people for their help in completing the work for this Project. I would like to express my sincerest gratitude to:

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Last but not least, heartfelt gratitude to my family who has been giving the courage and moral support to keep me constantly engaged in this project.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

Nowadays, the whole technology is moving towards renewable energy. Renewable energy is growing vastly as a possible alternative to non-renewable power generation. One of the most prominent purposes of the renewable energy is to produce small amount of energy through methods of Energy Harvesting.

The concept of Energy harvesting is to avail the energy that is usually available in the surroundings and convert it into useful electrical energy. Most people do not realize that there is alot of energy that is formed around them all the time. Energy can be harvested from sources such as vibrations, thermal and mechanical sources [1]. 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.

The idea of using revolving doors to harness Energy is relatively new in the market. A revolving door can be used as a new form of renewable energy by capturing wasted energy used to open the door and converting it into a power source [2].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. It also prevents the emission of harmful gases into the environment. This green energy solution makes use of an everyday occurrence to produce some electrical energy can be used for large range of low powered electronics.

1.2 PROBLEM STATEMENT

The demand of energy saving in a household is increasing day by day. Energy Harvesting is a field where various methods are implemented to produce small energy which can be used as alternative energy supply and contribute in saving the amount of total energy used in a house. There are various ways to produce energy on a micro level scale. These methods of Energy Harvesting contribute to produce Electrical Energy that is cheap and safe to the environment.

This project will use the Mechanical energy used to open a door and convert it into Electrical energy. The significance of this project is to contribute towards Energy Harvesting.

1.3 OBJECTIVES

- To study energy harvester systems with revolving doors.
- To develop a working prototype to produce electricity from the movement of a door.
- To estimate the power generation of a real size model.

1.4 SCOPE

In the past few decades, electricity consumption per capita all over world has increased largely. Therefore, there is a large load on generation of electricity through conventional methods. Sooner or Later it will lead to extinction of conventional power resources like coal, oil and gas. In order to lower the power load on conventional resources,there is a dire need of alternative non-conventional energy resources. Also the conventional sources increase pollution through green house. Therefore, with the implementation of more energy harvesting devices, more green energy can produced.

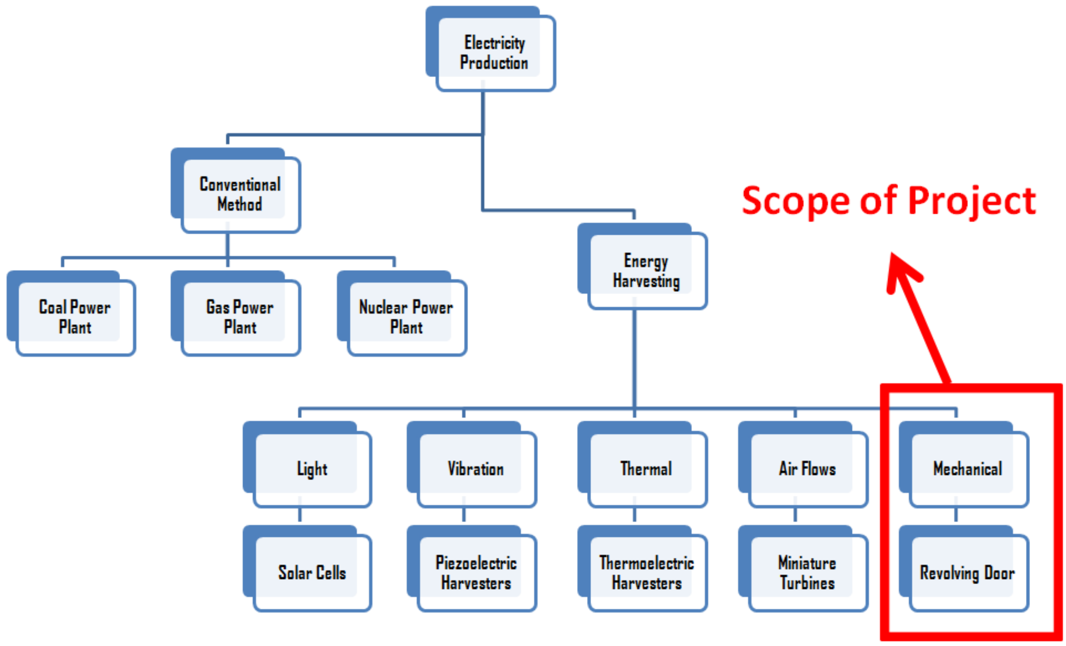


Figure 1 : Scope of the Project

CHAPTER 2
LITERATURE REVIEW

2.1 BACKGROUND

To understand the objectives of this project better, a study of energy harvesting and its sources has been carried from various sources. In order to continue this project it is very important that an extensive research is carried out on various types of energy harvesters that are currently being implemented.

2.2 ENERGY HARVESTING

Energy harvesting is best explained as a process in which energy is obtained from external sources and later stored for smaller electronic devices [3].This area of research is expanding rapidly due to its capability to provide reasons for replacing the conventional methods of producing electrical energy [4]. It is also known as “Energy Scavenging” From the name itself, it can be deduced that the power provided in this process has a very small amount. This small amount of power is usually used for low-energy electronics.

If the fuel input of Energy Harvesters is compared to some large-scale generations, the different in cost is immensely huge. While large-scale Electricity Generators feed on huge amount of fuels, the energy source for energy harvesters is obtained mostly from the surroundings and the operating cost is close to nothing.

Ambient Energy sources can be energy that is meant to be used for a different purpose. The Energy sources can be of vast number of forms totally depending upon the surrounding environment. There are many various types of Energy Harvesters situated in the built environment.

2.3 KINETIC ENERGY HARVESTING

2.3.1 PIEZOELECTRIC

The purpose of piezoelectric strip is to use the piezoelectric effect and convert mechanical strain into electrical energy. There are various sources for the strain. It can be produced by Human motion, seismic vibrations and acoustic noise. The most common use of piezoelectric effect is to generate mechanical energy by walking on a piezoelectric strip. This energy is converted into electrical energy which is later used to power various applications that require low power to operate. The devices that can be powered through Piezoelectric Energy Harvesting are pagers, cell phones, and sensors [5].

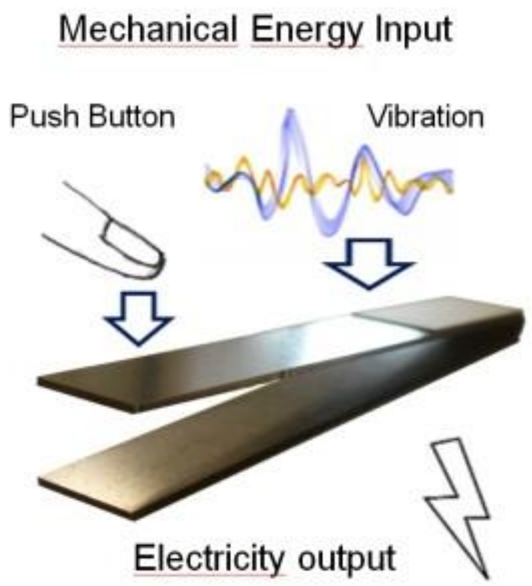


Figure 2: Working Principle of Piezoelectric Energy Generators [6]

2.3.2 BIOMECHANICAL

According to authors in [7], it is possible to power human heart-pacemakers using conversion of mechanicalenergy from vibrations of heartbeat to electricalenergy. It is noted in [4] that the power required to operate a modern pacemaker is 1µW. Even though, the power requirement is very low, batteries in the pacemaker still need to be replaced after a certain amount of time.

Figure 3: Applications of Biomechanical Energy Harvesters [8]

2.4 ELECTROMAGNETIC ENERGY HARVESTING

2.4.1 MAGNETOELECTRIC

Wasted vibrations are scavenged from the environment using Vibration-based Energy Harvesters, and converted into electrical energy to run small-scaleelectronic devices. Magneto-electric laminated composite (MLCs) have been used to create energy harvesters based on vibrations. It has the potential to generate large power outputs,due to the energy density being high and strong coupling [9].

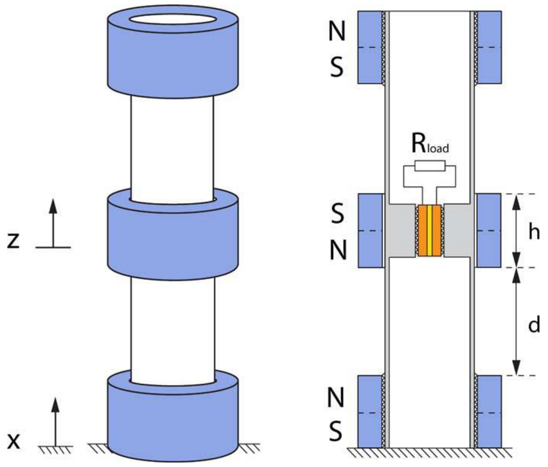


Figure 4: Mechanism of Magneto electric Energy Harvester [9]

2.5 THERMAL ENERGY HARVESTING

2.5.1 THERMOELECTRIC

Thermoelectric Energy Harvesting is also a very recent and important energy harvesting technique where thermal effects are used to produce electrical energy. The Seebeck effect is used to convert energy differencesbetween two regions having different temperatures into electrical energy [4]. However, voltage amplifier circuits are critically needed to convert the low output voltage to useable levels in energy harvesters based on thermal energy mechanisms.

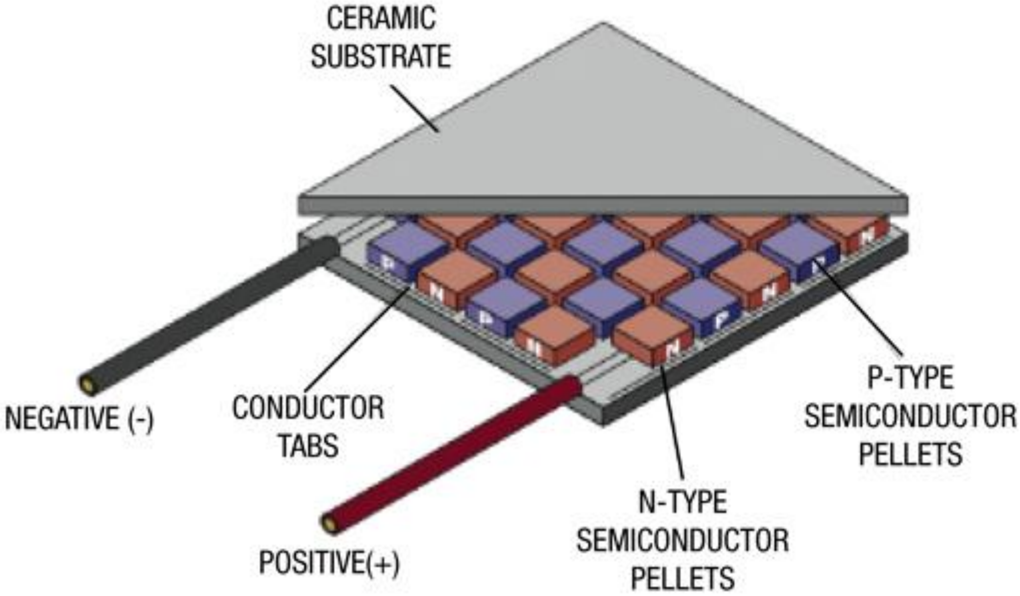


Figure 5: Mechanism of Thermoelectric Energy Harvester

2.6 A BRIEF STUDY OF ENERGY HARVESTING REVOLVING DOORS

The mechanism of a revolving door typically consists of a center shaft with three to four doors hanging on it.The shaft rotates around a vertical axiswithin a round enclosure. The main purpose of revolving doors is to reduce the heating or coolingrequired for the building. Another secondary purpose of revolving doors is toallow large numbers of people to pass in and out. The revolving door designed by authors in [2] helps to generate and conserve energy in a built environment.It produces green power when person passesthrough it. With the rotation of door, the motion of shaft is converted into sufficient speed by a pair of gears for producing electricity throughgenerator. Theoutput is stored in D.C battery after the voltage is regulated at a certain level.

The model consists of three main parts :

- Central Working Device – Revolving Door
- Gear System
- Output Device – Generator

Figure 6 : Current Mechanism of Energy Harvesting Revolving Door [2]

2.7 TORQUE AND ITS EFFECT

The ability of a force to rotate an object about a pivot is known as Torque. Torque is also defined as the cross product of the lever-arm distance and the force applied, which results in production of rotation.

The torque magnitude depends on two main things Firstly, the force applied affects the torque. Secondly, the length of the lever arm which connects the axis to the point where force is applied. The formula of torque is as following:

$$\tau = F\ X\ d$$

Where
τ = Torque Generated on the Shaft
F = Force applied to open the Door
d= Width of Door Panel

2.8 EFFECT OF LEVER ARM DISTANCE

Based on the research done by authors in [2], we can observe the effects of lever arm distance on Torque requirement. The method used by them is by varying the width of the point of Force application the figure below indicates the effect of leverage.

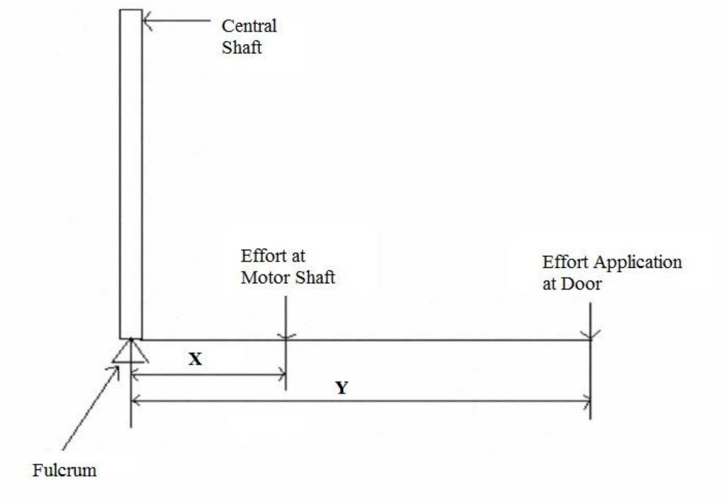


Figure 7: Lever Arm Diagram [2]

The figure above is retrieved from [2]. The fulcrum is the central shaft. The symbol X denoted the length of the Gear connected to the shaft while Y denotes the point where the force will be applied by the user.

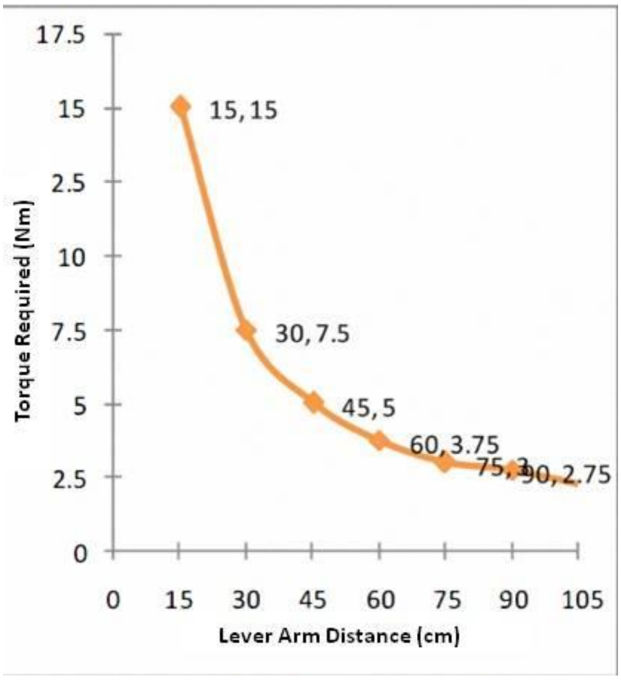


Figure 8: Torque Required against Lever Arm Distance [2]

Based on the research of authors in [2], it can be seen that the Lever Arm Distance has a great effect on the Torque required to open the door. As the Lever Arm Distance increases, the torque requirement decreases. From these studies, it can be noted that the width of the door plays an important role in the overall power produced by the Revolving Door.

CHAPTER 3
METHODOLOGY

3.1 SOLUTION PROCESSED

In order to carry out this project, a methodology was devised as a guide. The methodology was divided into two parts: Final Year Project I (FYP I) and Final Year Project II (FYP II). This was done to ensure that all tasks are completed on time. The description of FYP is as following:

During FYP I, the first step was to study the basics of energy harvesting and types of energy harvesters from various sources such as articles, journals, books and website. After that, a Gantt Chart was made to ensure that all tasks are achieved on time. A basic sketch was created for the design. This sketch acted as a guide in order to proceed with modeling. The scope of study and limitations was put into consideration and calculations and tests were conducted to know the parameters for the designs.

During FYP II, the main objective was to fabricate and test the prototype. Firstly, the materials were acquired from various sources. Some of the required objects were ordered online. Most of the material was readily available in the University. After the acquisition, the fabrication process was put into effect. The fabrication was completed within 6 weeks with the help of technicians. The prototype was tested for voltage and current outputs. Based on the output, the conclusions were made.

3.2 EXECUTIVE FLOW CHART

The process flow for this project is given on the next page. It includes all the steps taken in order to complete this project. The project starts with identifying the scope and objectives of the project, gather valuable related literature for this topic which involves going through researches conducted on Revolving Door Energy Harvesters and also the literature on the principals and laws that will be used in processing the data later onwards. After that a conceptual design is made on software and then fabricated. The final prototype is attached to the PASCO interface and the data is plotted. The final data is presented to the supervisor. The following Figure shows the executive flow chart for this project:

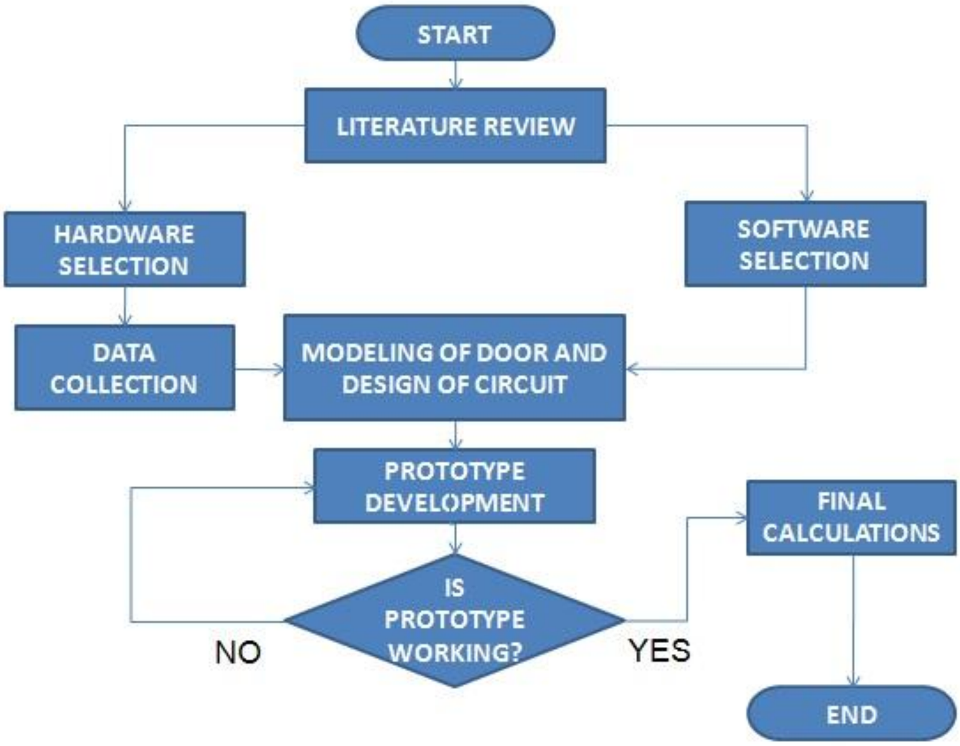


Figure 9: Executive Flow Chart

CHAPTER 4

CONCEPTUAL DESIGN

In order to start working on the design of the prototype, it was necessary to decide whether the door will have three panels or four panels. Therefore, a sketch was acquired from a product manual of commercial Revolving Door. The difference was noted between the two designs. The figure shows the sketch.

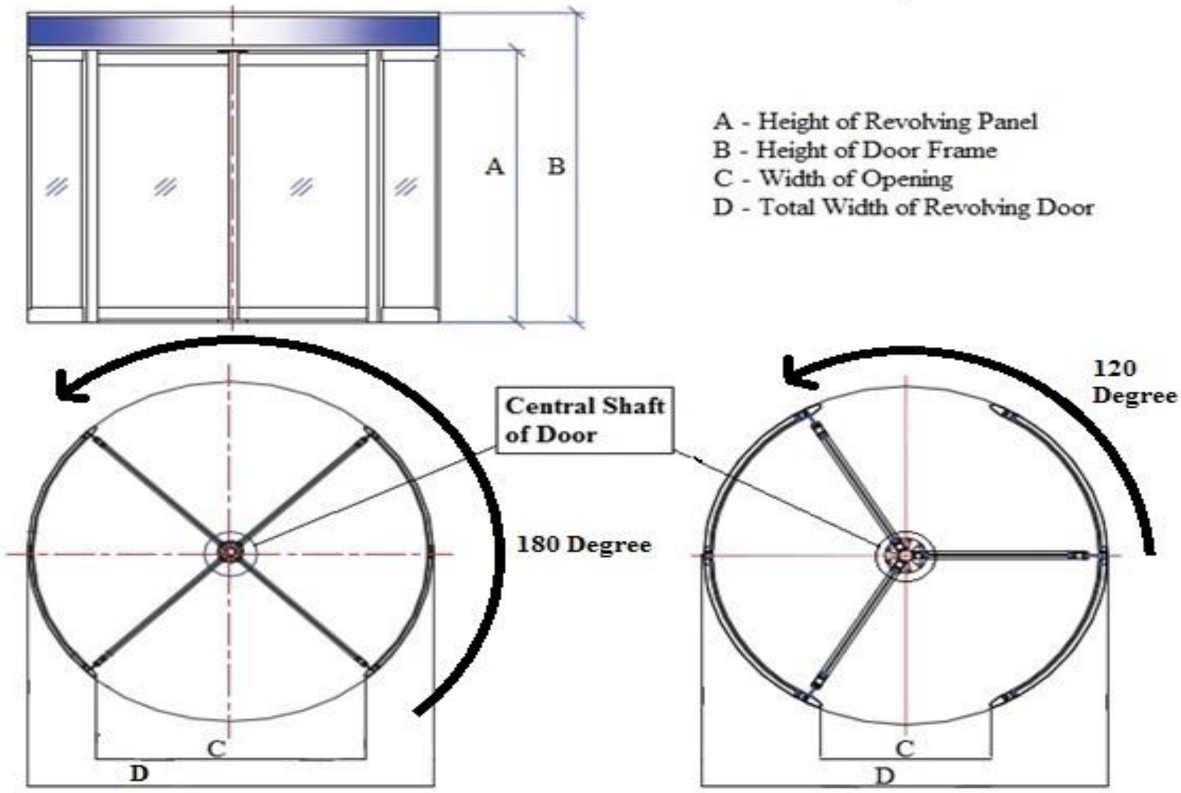


Figure 10 : Sketch of a Three and Four Panel Revolving Door Design

From the sketch, the difference is noted between the designs of Four Panel and Three Panel Revolving door. 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 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. To solidify this claim, further investigation is done for this purpose. A model is made for both designs using Solid Works Software and respective calculations are done.

4.1 DESIGN AND CALCULATION OF THREE PANEL DOOR

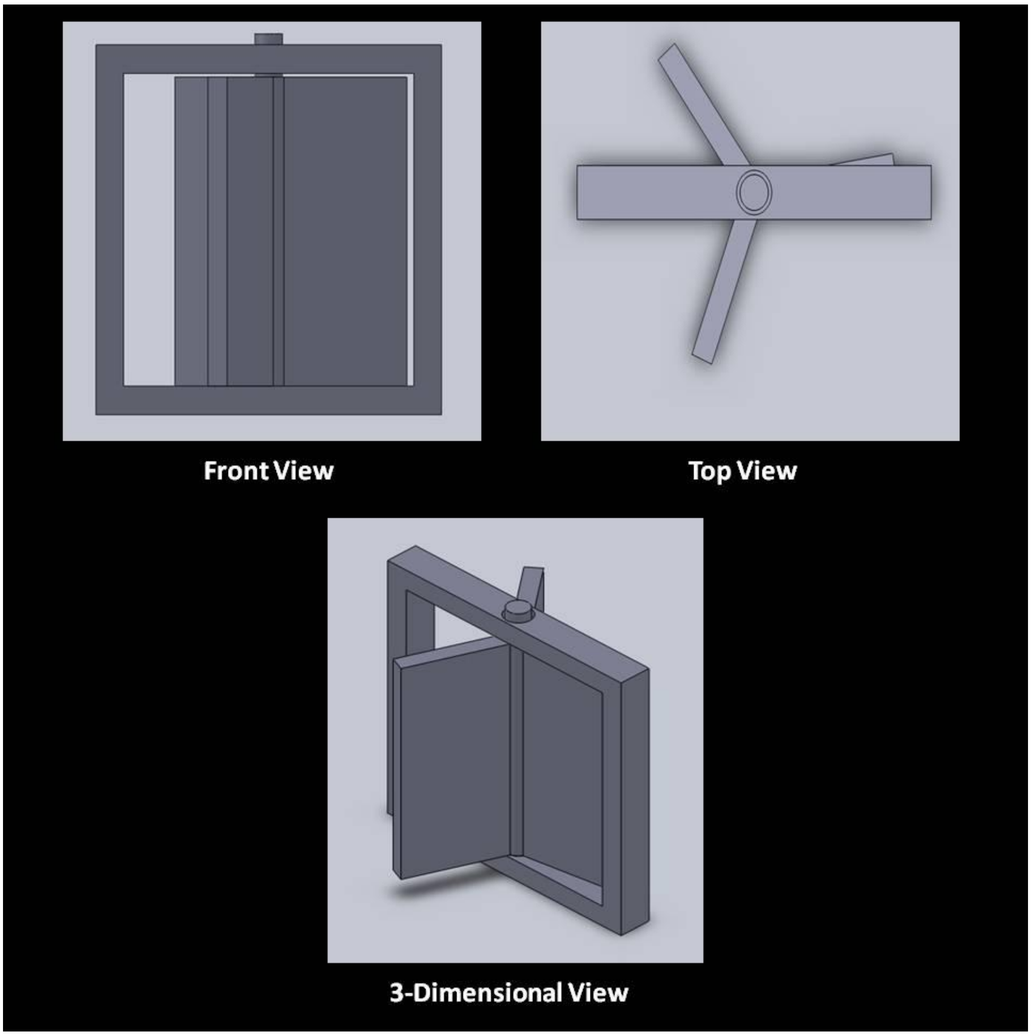


Figure 11: Model of a Three Panel Revolving Door

Door Opening = 120 Degree

Assuming Time to open door = 2 seconds

$$\therefore RPM\ of\ Door = \left(\frac{120}{360}\right)\left(\frac{60s}{2s}\right) = 10\ rpm$$

4.2 DESIGN AND CALCULATION OF FOUR PANEL DOOR

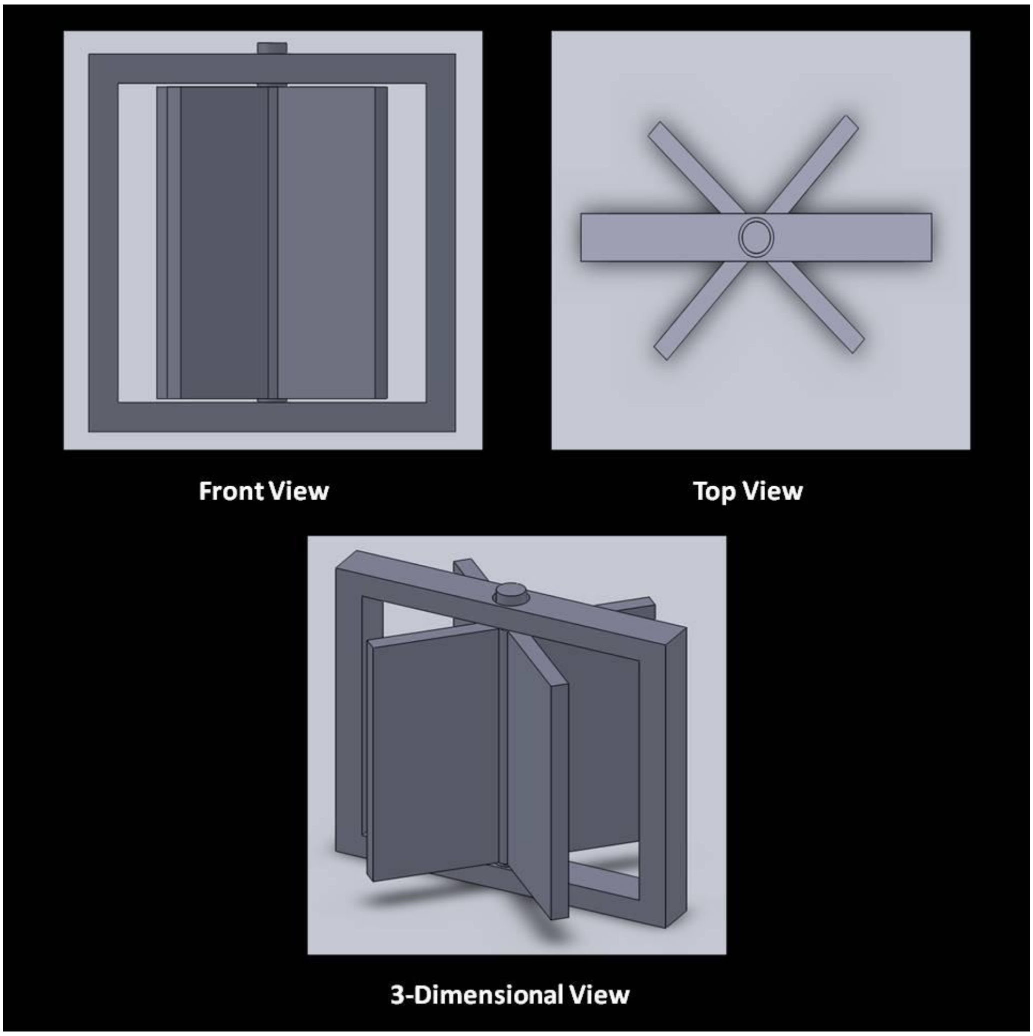


Figure 12: Model of a Four Panel Revolving Door

Door Opening = 180 Degree

Assuming Time to open door = 2 seconds

$$\therefore RPM\ of\ Door = \left(\frac{180}{360}\right)\left(\frac{60s}{2s}\right) = 15\ rpm$$

Based on the design and calculations, it can be stated that Four Panel Door will produce more RPM as compared to Three Panel Door. Therefore, it is chosen as the design of our prototype. It is to be noted that the final drawing may vary in dimensions. This is just a conceptual design in order to understand how the prototype will look like after fabrication.

CHAPTER 5

FABRICATION OF THE PROTOTYPE

In order to begin fabrication of the prototype, a step by step procedure was made. The need for a procedure was essential so that the process can be traced in case of an error or a fabrication mistake. The procedure was strictly followed. The steps are as following:

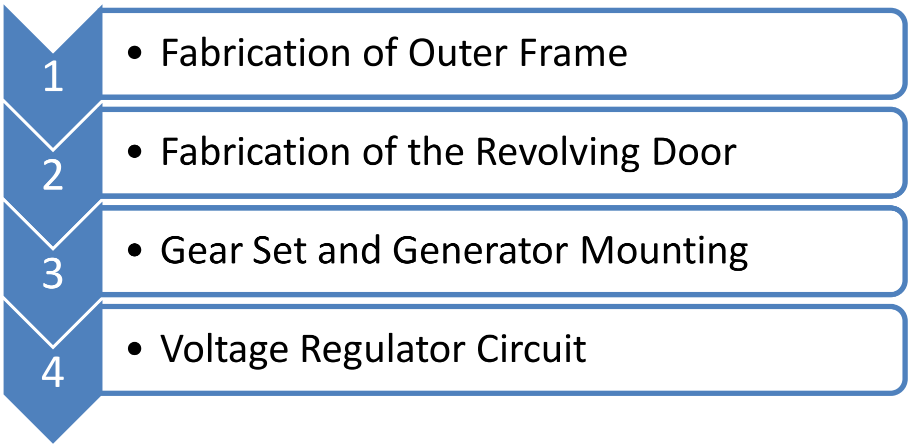


Figure 13: Prototype Fabrication Steps

5.1 FRAME STRUCTURE

The purpose of the frame structure is to hold the revolving door, gears and generators in place. The material for the frame is Hollow Steel bars. The size of the bars was chosen to be 1 inch X 1 inch. The diagram below shows the finalized design for the frame.

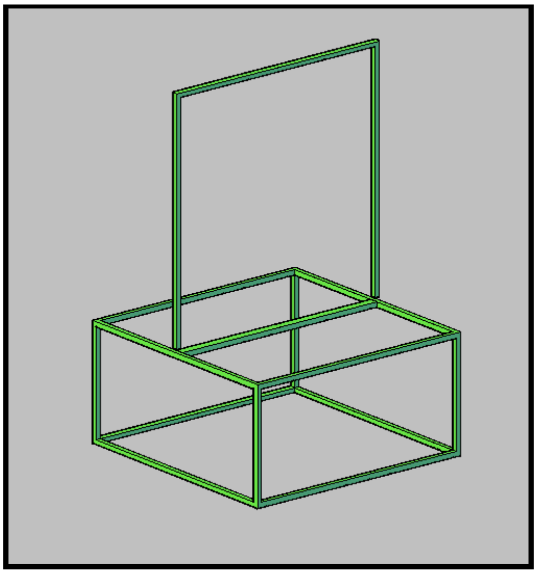


Figure 14: Design of outer frame of prototype

Using the diagram as a reference, the frame was fabricated. Firstly, hollow steel bars were cut into appropriate sizes. Then, the smaller steel bars were welded according to the design. After the welding was done, the frame was given finishing to smoothen the points where welding was done.

Figure 15: Outer frame of the Prototype

5.2 DOOR STRUCTURE

The structure of the revolving door is the main part of the prototype. The four panel design was chosen for the revolving door as it was proven in Chapter 4.2 that four panel door will have more revolutions per minute. The diagram below shows the finalized design for the Revolving door.

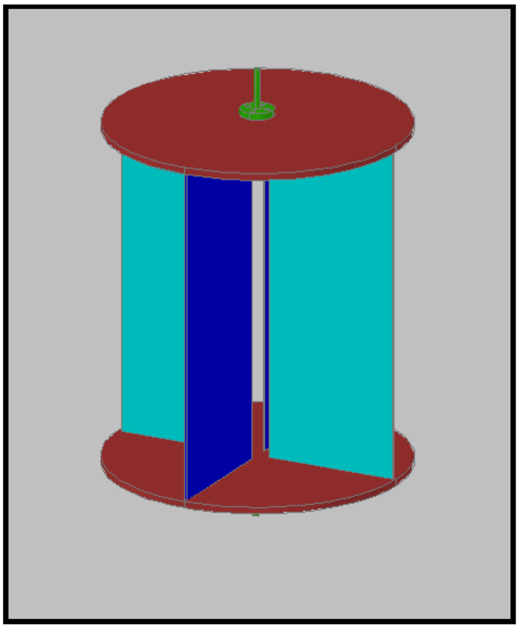


Figure 16: Design of Revolving Door

The material used to fabricate the revolving door was Acrylic glass of 4mm thickness. In order to hold the pieces of acrylic glass together, aluminum angle and rivets were used. The figure below shows the revolving door structure.

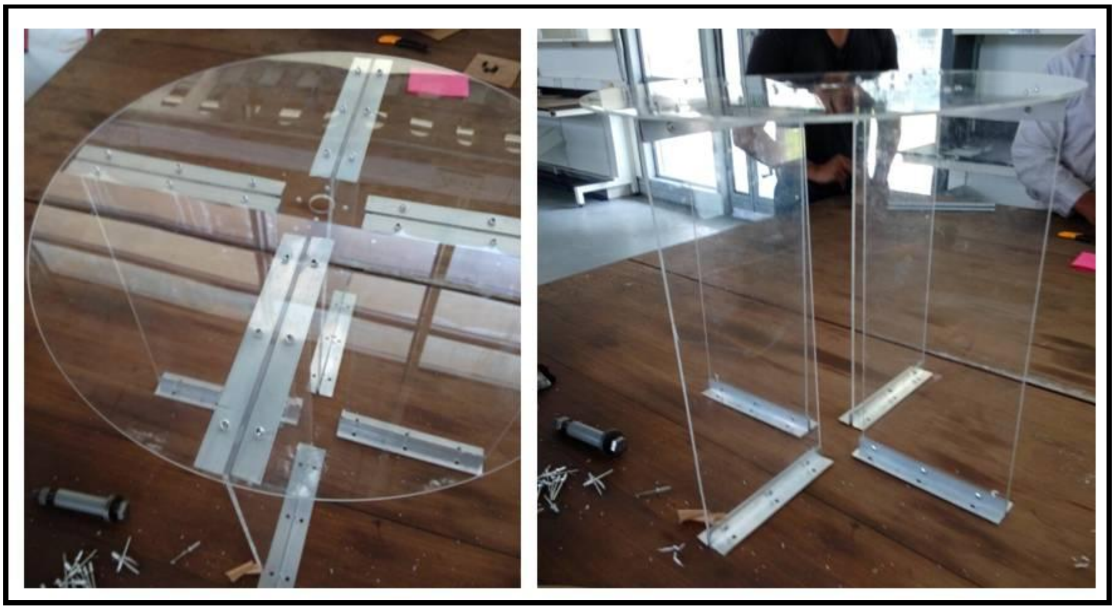


Figure 17: Revolving Door Structure (Top View and Side View)

5.3 GEAR AND GENERATOR SPECIFICATIONS

The selection of the Generator and Gear is also a very important attribute 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 figure below shows the size of the generator that was selected for the prototype.

Figure 18: Generator used for the project (Side View)

Figure 19: Generator used for the project (Top View)

From the figure above, it can be seen that the Generator has a head with three holes. It can be easily mounted on the outer frame of the door. The table below shows further specifications of the generator.

OUTPUT VOLTAGE	5V- 24V
OUTPUT CURRENT	1500 MA
SPEED	120 RPM
MAX LOAD : 20 WATTS	20 WATTS
WEIGHT	490G

Table 1: General Specifications of the Generator

The Gears are also important part of the project as the ratios between the gears determine the number of revolutions given to the generator. The more number of revolutions, the stronger the current. The type of gear chosen was Steel Spur Gear. The figure below shows the pair of Gears chosen for the project and the table below shows the specifications of the Gears.

Figure 20: Steel Spur Gears

CATALOG NUMBER	SS1.5-20B	SS1.5-100J15
NO. OF TEETH	20	100
RATIO	1	5
BORE DIAMETER	8	15
HUB DIAMETER	24	60
PITCH DIAMETER	30	150
OUTSIDE DIAMETER	33	153

Table 2: General Specifications of the Gears [11]

5.4 PROTOTYPE ASSEMBLING

After the acquisition of the gears and generator, the prototype was assembled. The importance of this process is of great value. It is because the door should be mounted on the frame in a much aligned manner. The alignment is necessary so that the shaft can be inserted through the center of the door. It is also required to balance the gear on the shaft. The figures below show the completed prototype.

Figure 21: Prototype after Assembling

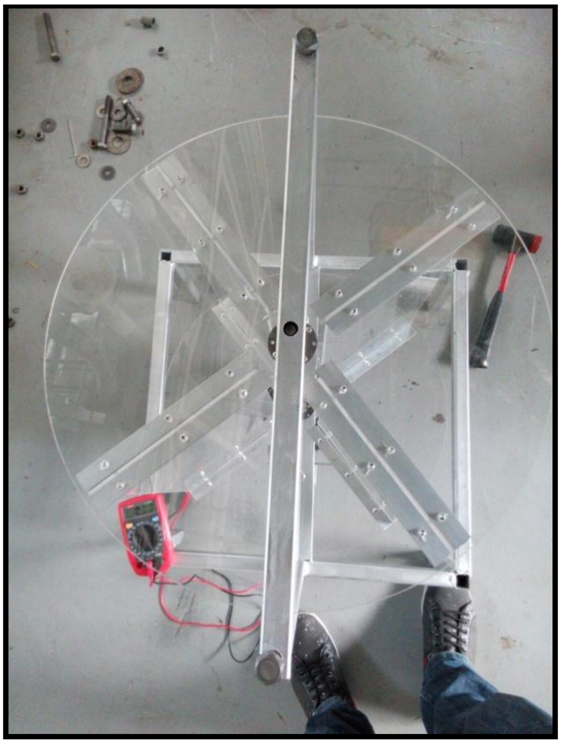


Figure 22: Top View of the Prototype

Figure 23: Side View of the Prototype

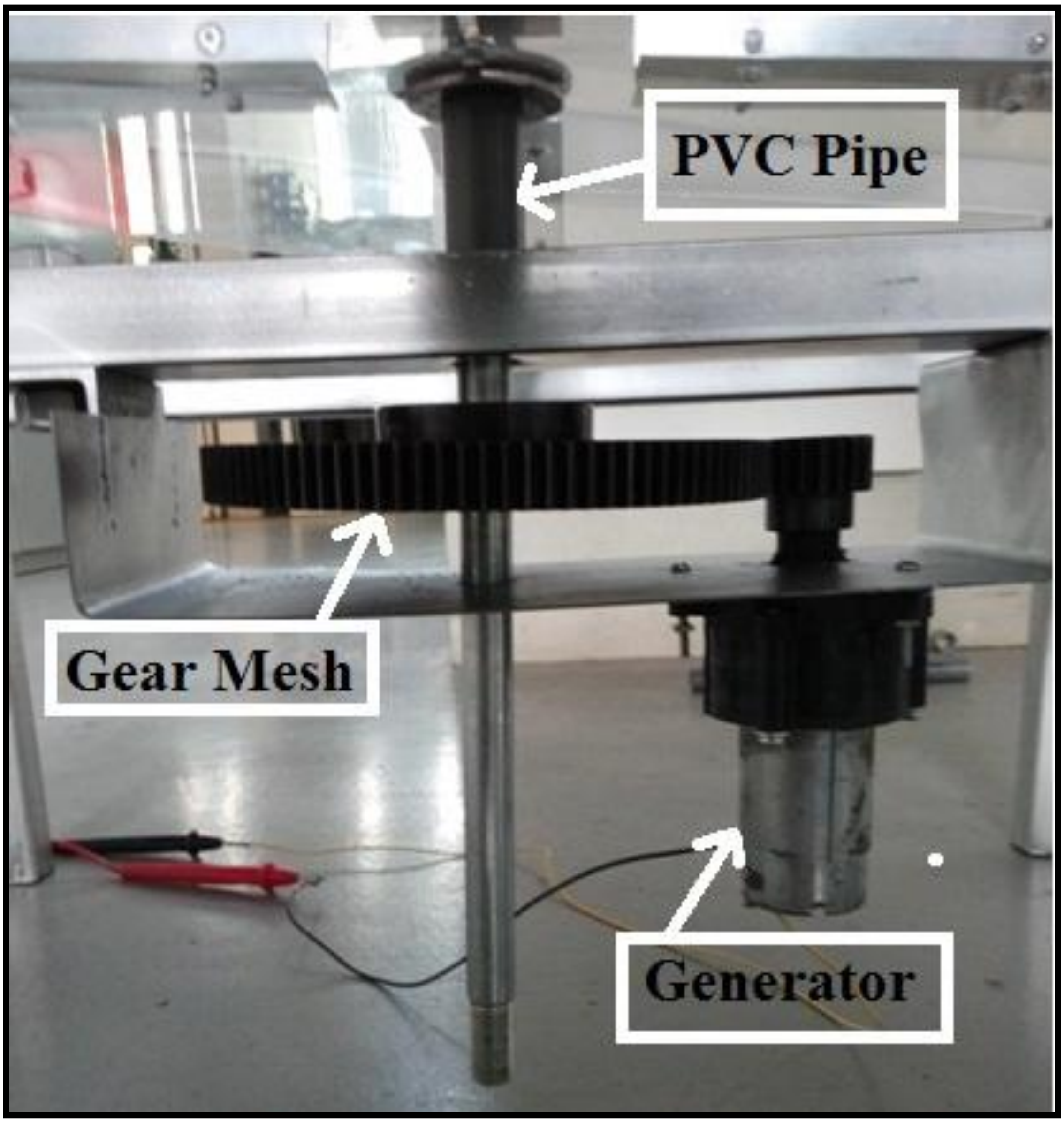


Figure 24: Gear Mesh attached to Generator

As it can be seen in the figure above, there is a PVC pipe between the door and the frame. The purpose of the PVC pipe is to elevate and balance the door. The Gear is attached to the shaft using tightened Allen key screws. The larger gear is in mesh with the smaller gear. The smaller gear is attached to the generator shaft using tightened Allen key screws also. Therefore, the whole structure stays intact and moves swiftly when the door rotates. The figure below shows a close insight of the two gears meshed together.

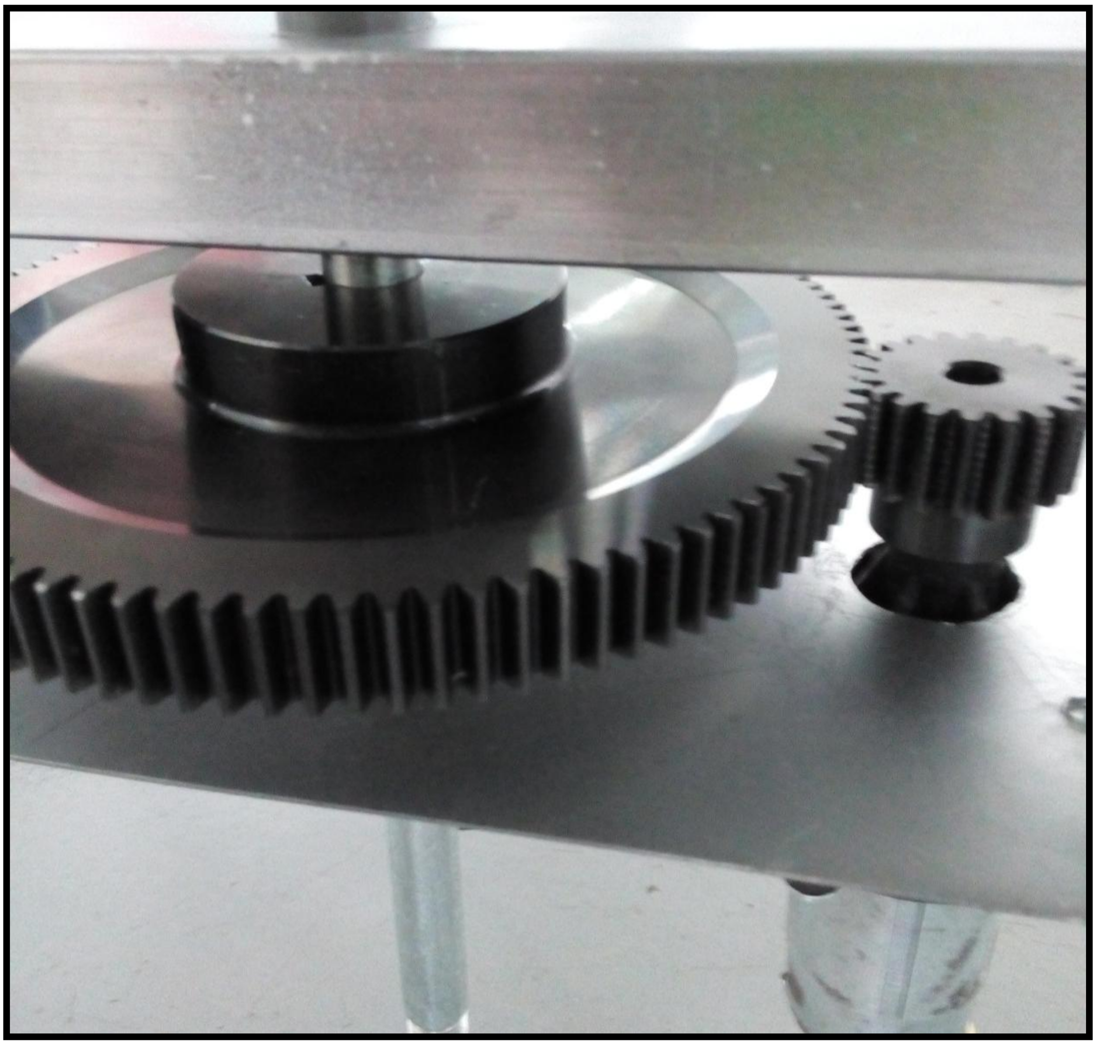


Figure 25: Close Insight of Gear Mesh

CHAPTER 6
TEST RESULTS AND CALCULATION

6.1 TESTING PROCEDURE

The purpose of testing the prototype was to find the relation of output voltage over time and output current over time. The results cannot be measured using a multi-meter as the output cannot be stored and the accuracy is questionable. Therefore, a more comprehensive tool is needed to measure the output voltage and output current.

The testing procedure was carried out under the technician's supervision. It 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) [12]. Users can 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 analyzes the data measured by the sensor.

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 [13]. It also has the capability to export the data for further analysis. The figure below shows the device and the software used for testing.

Figure 26: PASCO 850 UNIVERSAL INTERFACE

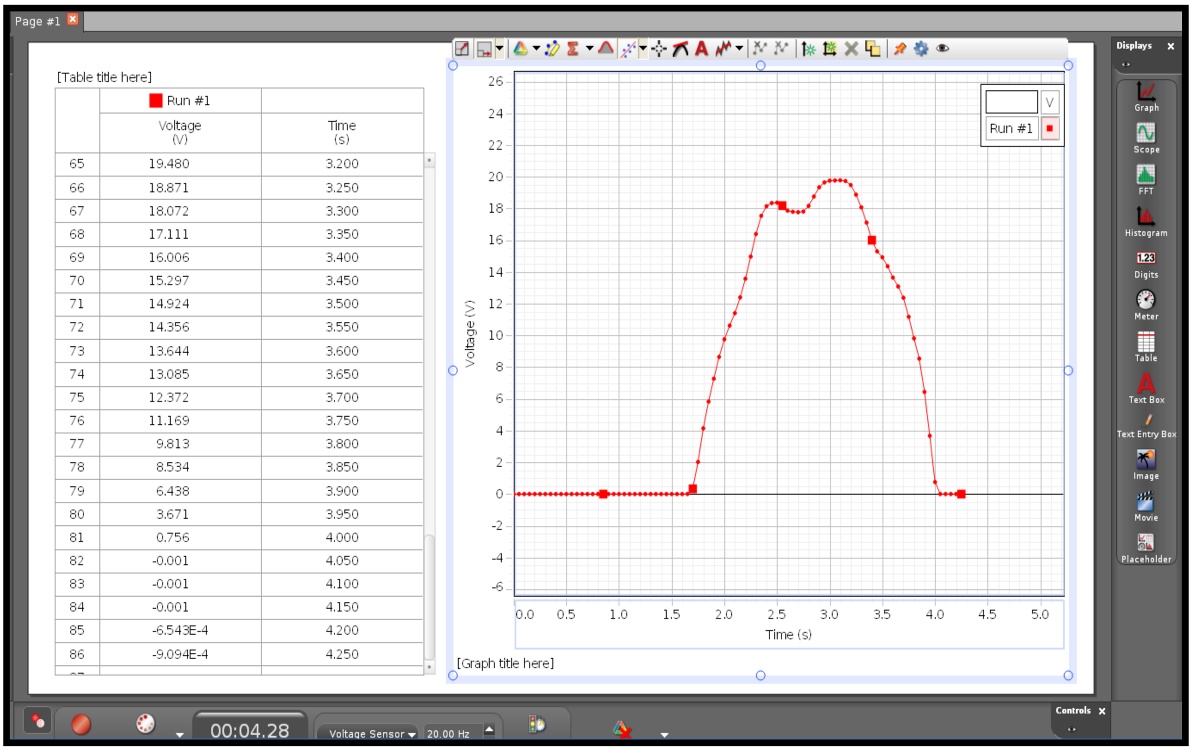


Figure 27: PASCO Capstone Software

Firstly, the output voltage was calculated. The prototype was connected to the PASCO device directly. The PASCO device was interfacing with the PASCO software. When the door is rotated, the software records the data for output voltage against time. This was repeated a total of three times. The results were saved for analysis.

In order to record current, a 100 ohm resistor was connected in series with the prototype. When the door is rotated, the current running across the resistor is recorded. An increase in resistance results in lesser current. This process was repeated a total of three times. The results were saved for analysis.

6.2 TEST RESULTS

The results gathered from the testing procedure were in numerical table form. They were inserted into a Microsoft Excel Spreadsheet. The average results were calculated using formula functions and the graphs were reformed.

<u>**Results for Output Voltage against Time**</u>

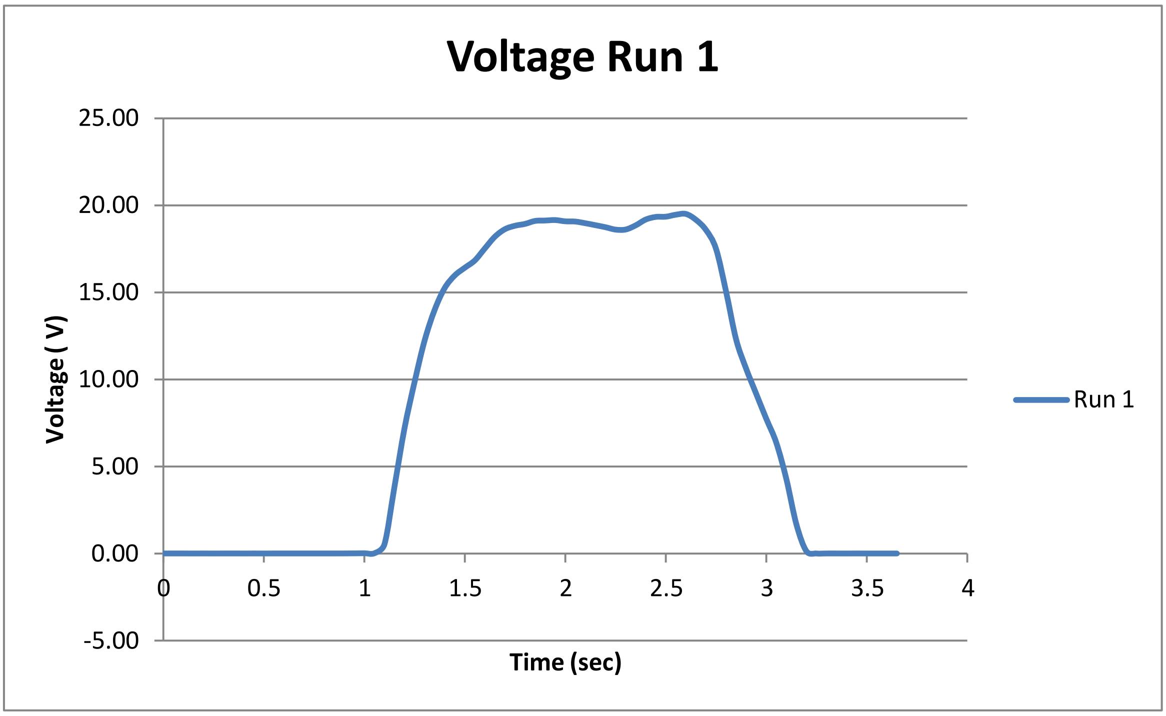


Figure 28: Output Voltage ‘First Run’

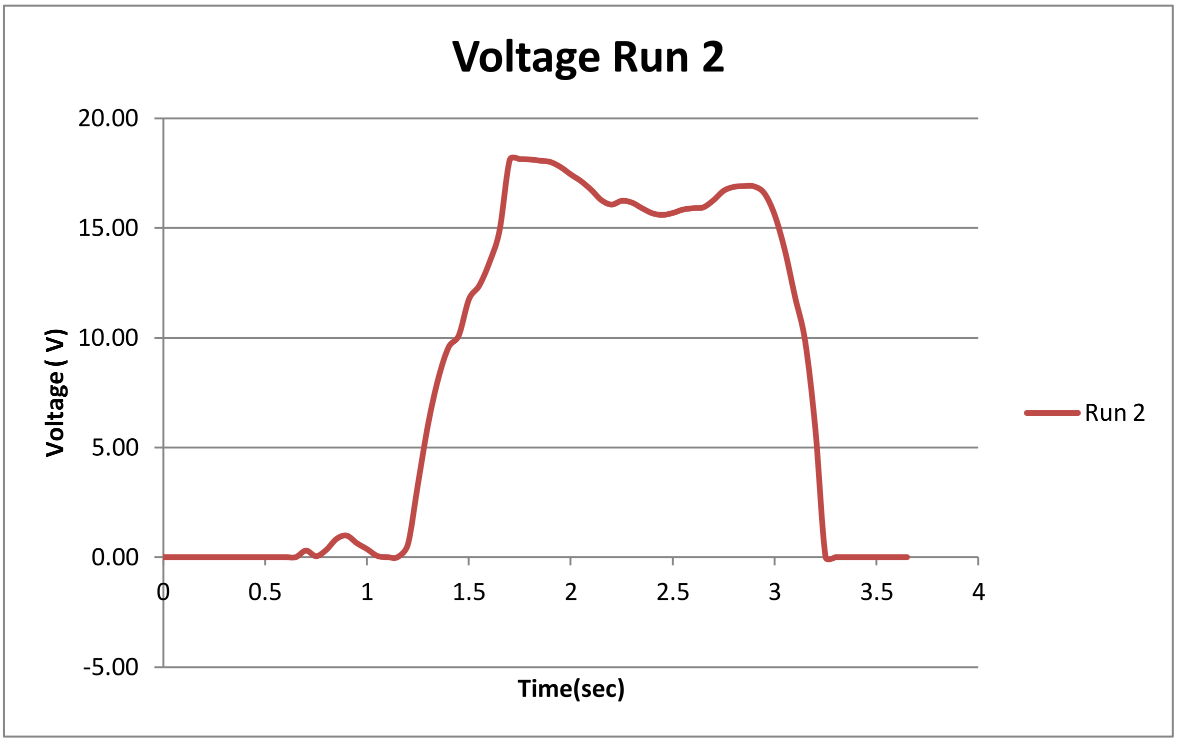


Figure 29: Output Voltage ‘Second Run’

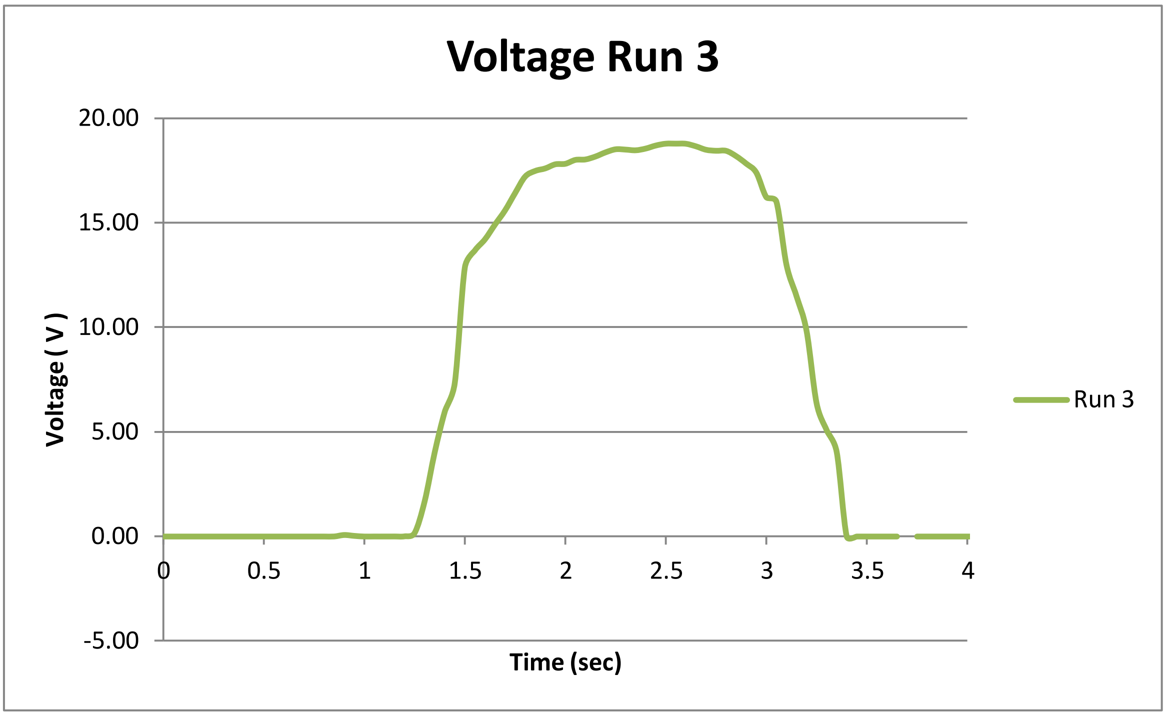


Figure 30: Output Voltage 'Third Run'

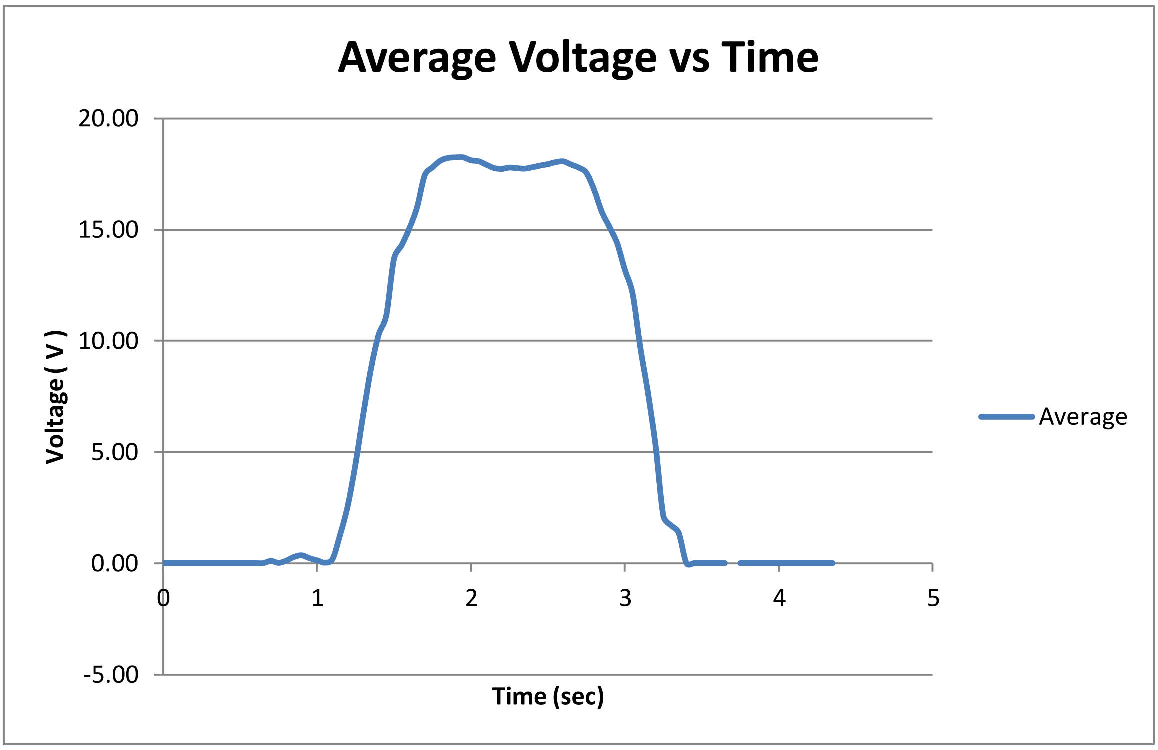


Figure 31: Average Voltage against Time

Results for Output Current against Time

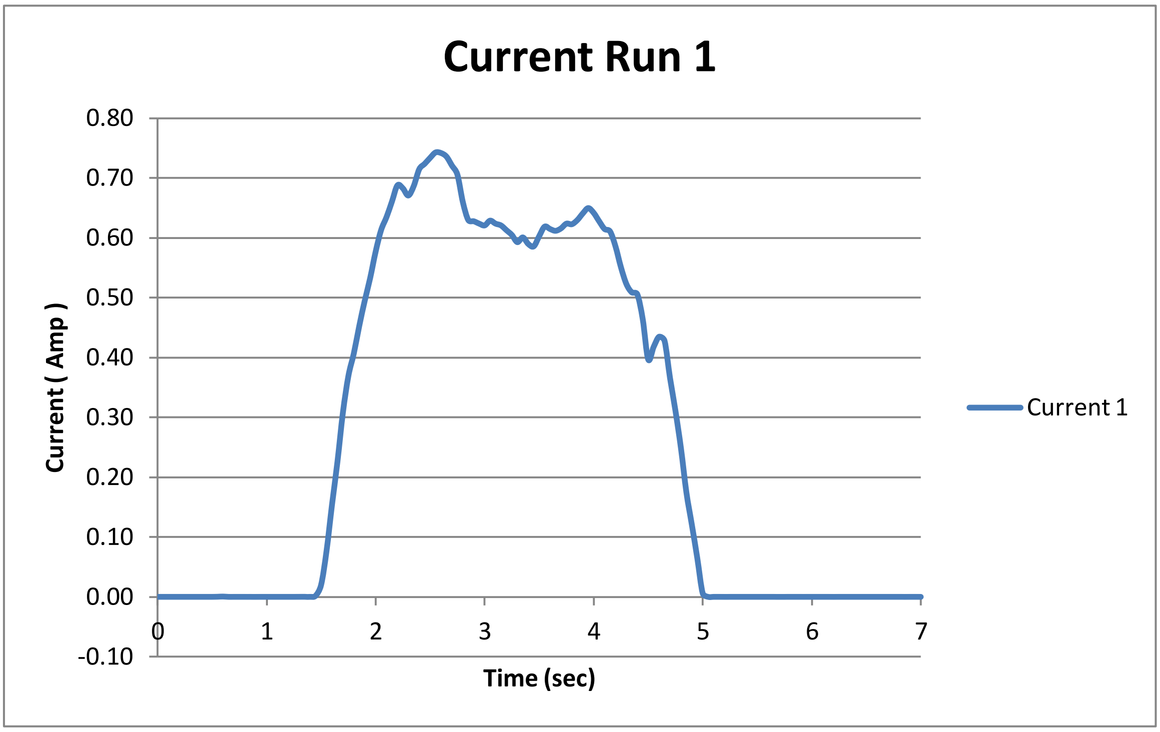


Figure 32: Output Current 'First Run'

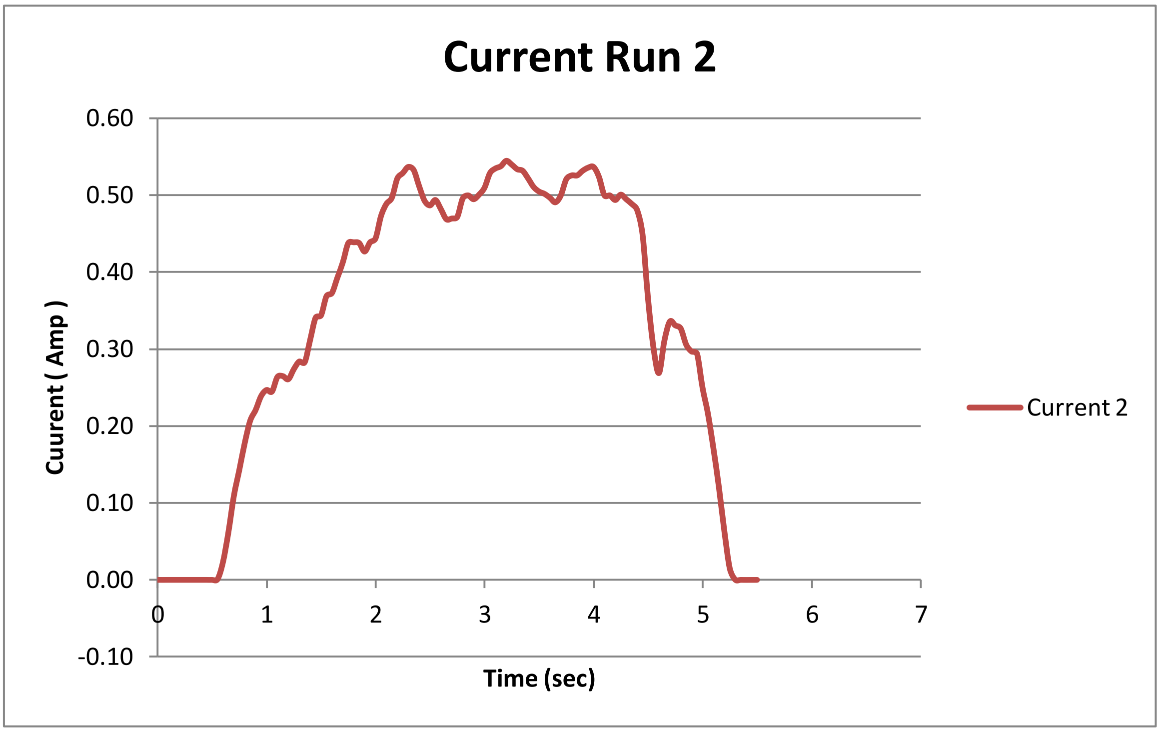


Figure 33: Output Current 'Second Run'

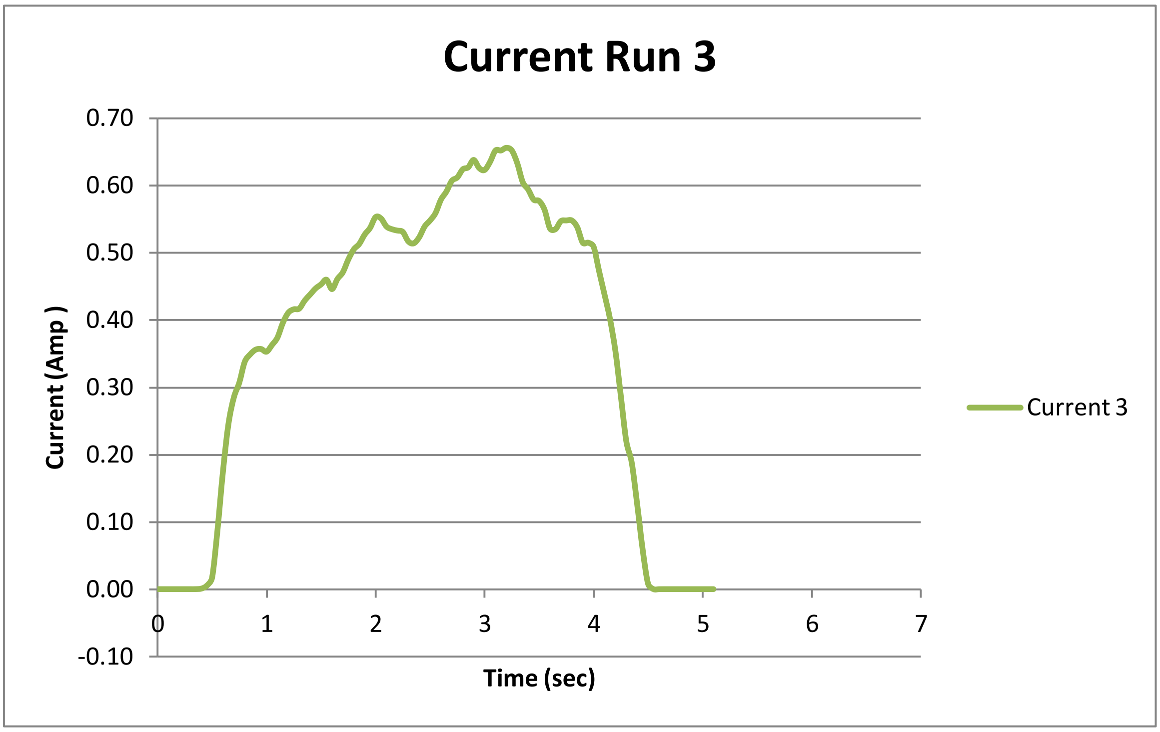


Figure 34: Output Current ‘Third Run’

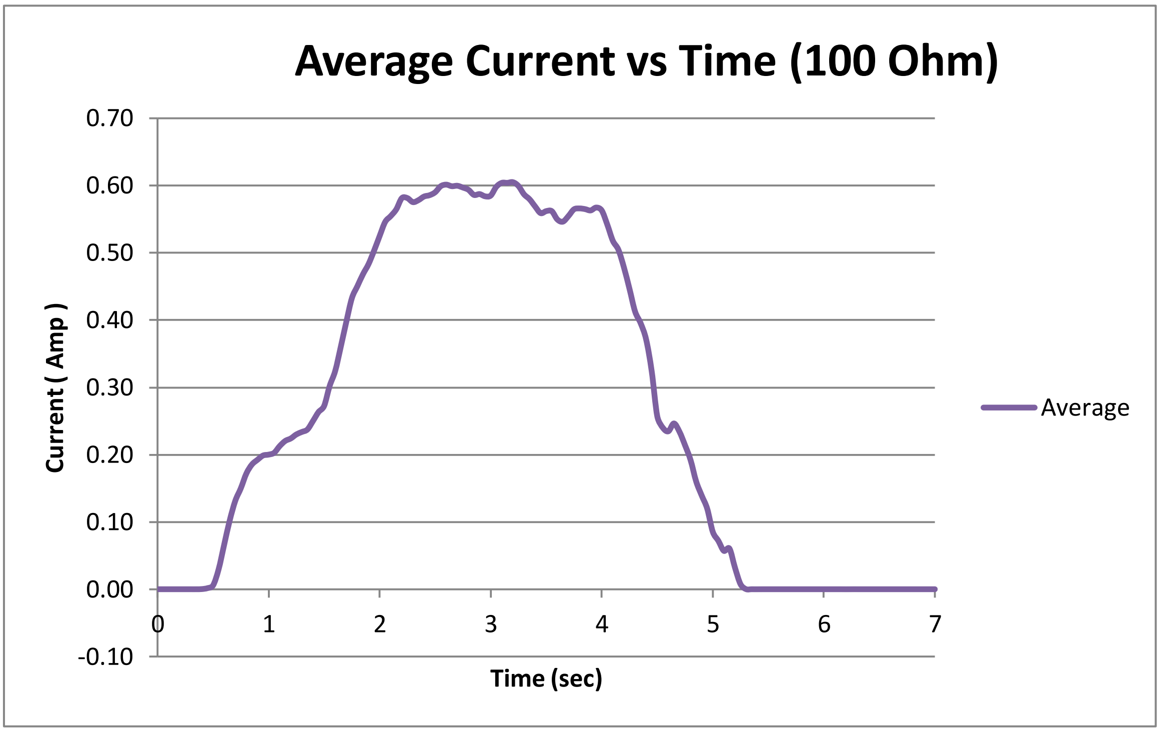


Figure 35: Average Current against Time (100 Ohm)

Results for Average Power against Time

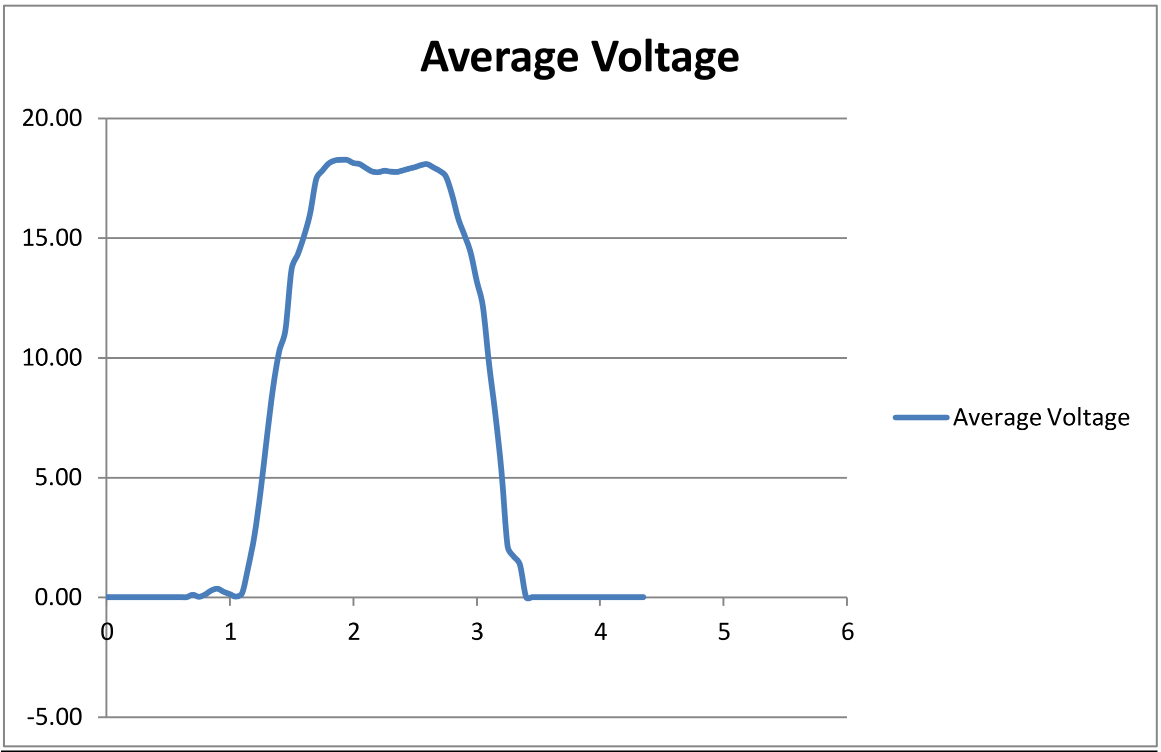


Figure 36: Average Voltage against Time

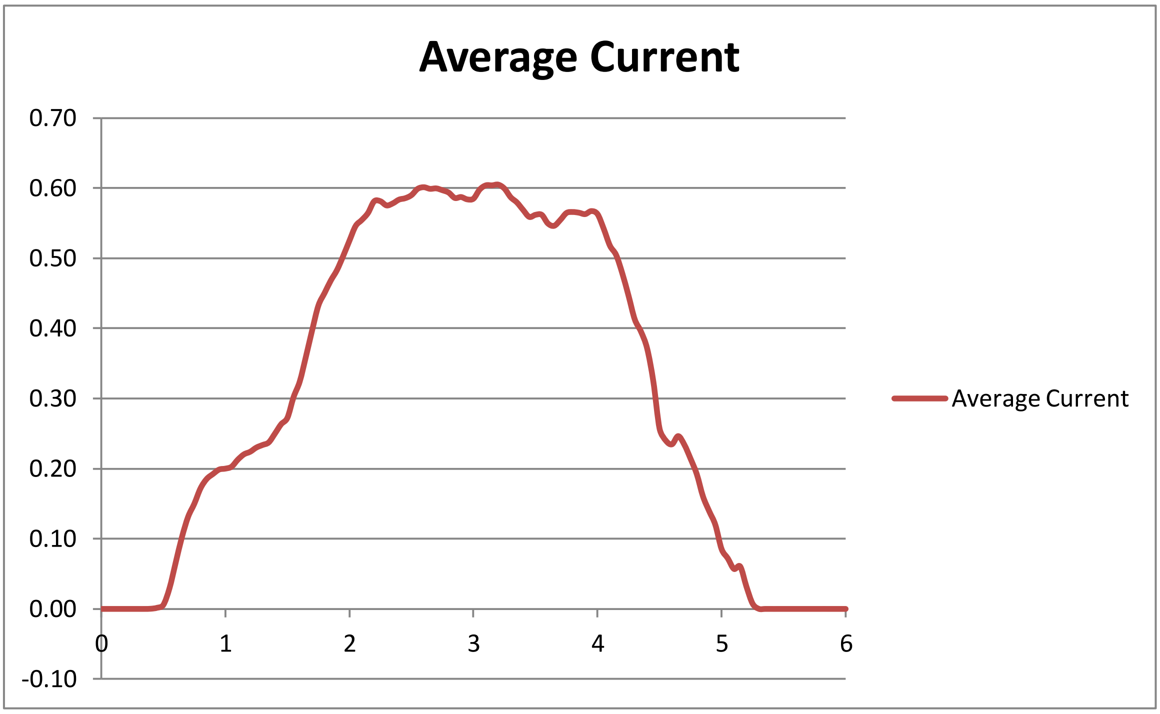


Figure 37: Average Current against Time (100 Ohm)

The results from the average output voltage and average output current were used to find the average power output. The results were multiplied using ‘Product’ function in Microsoft Excel. The graph of Average Power against time was formed and is shown in the figure below.

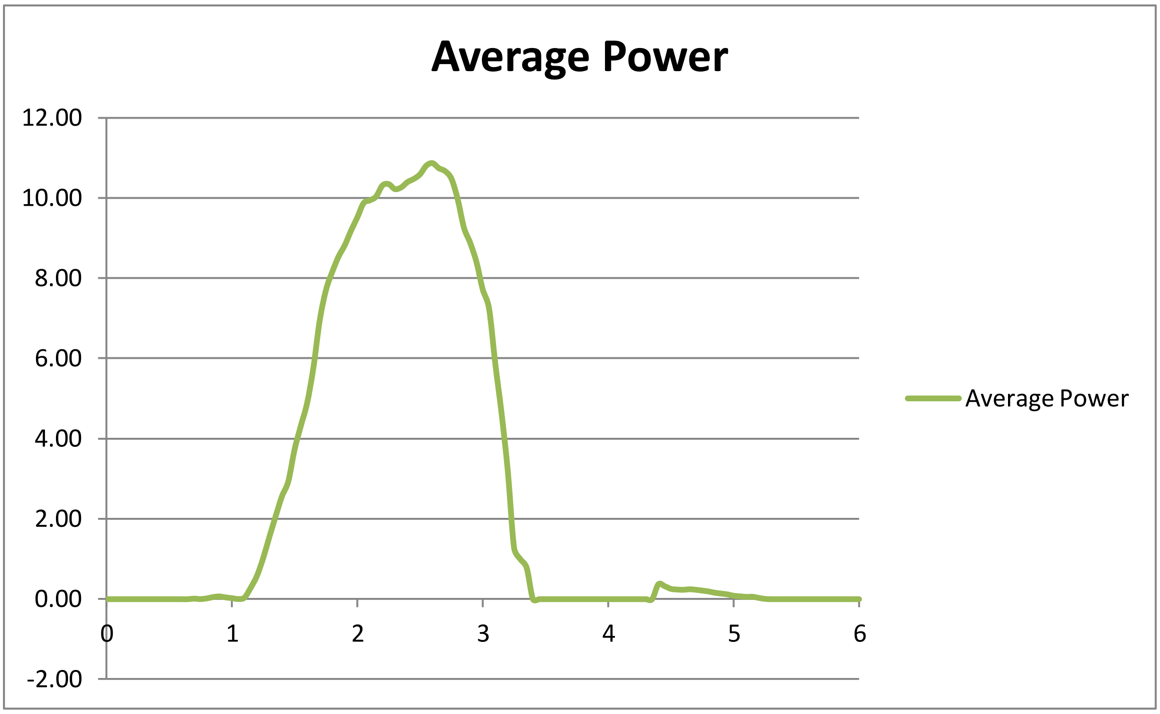


Figure 38: Plot of Average Power against Time.

From the graph, it can be seen that the peak power is 10.86 watt per push. The energy generated per push can be calculated from the graph. It is represented by the area under the graph. The equation of the graph is extracted from the results using Microsoft Excel.

$$y = -8.5558\,x^2 + 39.868\,x - 35.782$$

The X – Intercepts are ‘1.213’ and ‘3.45 ’. Therefore, energy generated per push is:

$$Energy\ generated\ per\ push = \int_{1.213}^{3.45} -8.5558\,x^2 + 39.868\,x - 35.782 \quad dx$$

$$Energy\ generated\ per\ push = \mathbf{15.67\ Joules}$$

6.3 CALCULATION AND DISCUSSION

After some research, 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 [14].

Figure 39: 1 Utama Shopping Mall in Kuala Lumpur

Calculations

Assuming that every person that comes in the mall has to exit through the same door. If the number of people to enter the mall in a single day is 60000, we can make the following assumptions:

$$Number\ of\ times\ the\ door\ is\ rotated\ in\ a\ day = 120000$$

However, it is practically not possible to rotate the door 120000 times a day. The mall operates from 10 am to 10 pm. Therefore, the door can be used for 12 hours. It is noted that the door can rotate a maximum of **38000** times in a day.

Assuming 38000 rotations in a day

$$\text{Total Energy produced in a day} = (38000)(15.67\ \text{Joules})$$

$$Total\ energy\ per\ day = 595460\ Joules$$

In order to calculate Kilowatt Hour

$$Kilowatt\ Hour = \left(\frac{595460\ Joules}{3.6\ \times 10^6 Joules}\right)$$

$$Kilowatt\ Hour = 0.165\ kWh$$

$$Power\ produced\ yearly = 0.165\ kWh\ \times 365\ days$$
$$= \mathbf{60.225\ kWh/year}$$

Carbon Credit Calculations

The purpose of these calculations is to show how much this project contributes 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 [15].

$$Coal\ saved\ per\ year = \frac{60.225\ kWh}{2\ kWh} = \mathbf{30.113\ kg}$$

$$CO2\ saved\ from\ being\ released\ into\ environment = 30.113\ \times\ 2.93kg$$

= **88.23 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.

CHAPTER 7
CONCLUSION AND RECOMMENDATION

7.1 CONCLUSION

In the end the prototype of the Revolving door proved out to be working and a success. The prototype was successfully fabricated. The prototype was designed using computer aided design software: AUTOCAD, The outer frame and Revolving Door was designed and fabricated on time. The gear and generator were successfully mounted on to the frame. It was made sure everything was properly aligned. The gear mesh stepped up the revolution of the door. The rotation of the generator produced voltage which was measured using PASCO UNIVERSAL INTERFACE and interfacing was done using PASCO Capstone. The results for average voltage, average current and average power were plotted against time. These results were used for analysis and the Energy per push was calculated. This shows that the Revolving Door has enough potential to produce Electricity and it should be implemented in busy public places.

7.2 RECOMMENDATION

As this report draws to an end, there are a certain number of recommendations that are to be suggested for further expansion of this project. Firstly, the size of the revolving door should be varied to find out the effect it has on the output values. The gear ratio can be altered in order to find the most optimized ratio for the output values. The type of generator can be changed to find out the difference. The most optimized combination should be selected. The testing should be attempted several times to get a smoother average curve. There are some modifications that can be made to the project. The generator can be connected to a charge controller and charge a battery each time the door is rotated. The charge stored in the battery each time should be calculated as well. This was not possible in the current project due to time constraint.

REFERENCES

1. Dymarski, P., Grabham,N., Beeby, S. and Tudor, M. (2011): “Survey of Potential Energy Harvesting Solutions for use in the built environment”,Ict for sustainable homes Conference 2011, Nice, 24-25 October 2011

2. Murthya,M.S.,Patila, B.V.S., Sharmaa, S.V.K., Polema,B., Koltea,S.S. and Dojia. N (2011): “Revolving Doors Producing Green Energy”, IEEE First Conference on Clean Energy and Technology CET

3. Retrieved from http://en.wikipedia.org/wiki/Energy_harvesting/ on 11 February 2014

4. Michael C. Hamilton, (2012): “Recent Advances in Energy Harvesting Technology and Techniques”,978-1-4673-2421-2/12/$31.00 ©2012 IEEE

5. Christopher A Howells (2009): “Piezoelectric energy harvesting”, Energy Conversion and Management 50 (2009) 1847–1850

6. Zervos, H , "Piezoelectric energy harvesting: Developments, challenges, future". RetrievedJanuary , 2013 Available: http://www.idtechex.com/research/articles/piezoelectric-energy-harvesting-developments-challenges-future-00005074.asp

7. M. A. Karami and D. 1. Inman, "Powering pacemakers from heartbeat vibrations using linear and nonlinear energy harvesters," Appl. Phys.Lett., vol. 100, pp. 042901,2012.

8. "Energy harvesting knee brace". RetrievedJanuary , 2013 Available: http://www.energyharvestingjournal.com/articles/energy-harvesting-knee-brace 00001366.asp?sessionid=1

9. Yang Zhu and Jean W. Zu (2012): “A Magnetoelectric Generator for Energy Harvesting From the Vibration of Magnetic Levitation”, IEEE TRANSACTIONS ON MAGNETICS, VOL. 48, NO. 11, NOVEMBER 2012

10. "People Powered Fluxxlab Revolution Door". Retrieved, 2013 Available: http://www.igreenspot.com/people-powered-fluxxlab-revolution-door/

11. Retrieved from https://www.khkgears.co.jp/khkweb/search/sunpou.do?indexCode=4&lang=en&referrer=series&seihinNm=SS1.5-12&curPage=default#SS1.5-12 on 19 July 2014

12. “850 Universal Interface Instruction Manual”,PASCO,Roseville, CA, 2014

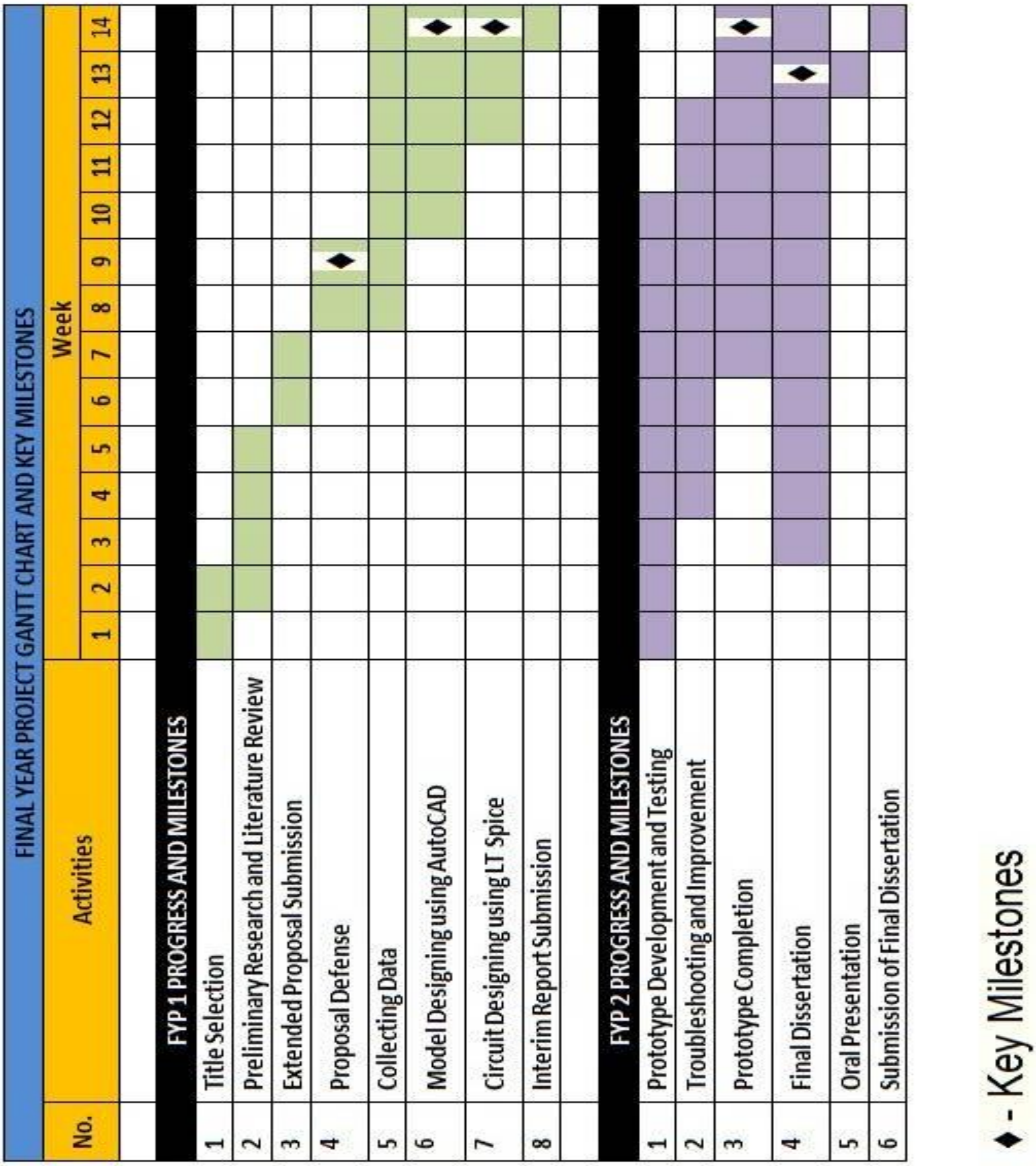
13. Retrieved from http://www.pasco.com/prodCatalog/UI/UI-5000_850-universal-interface/#overviewTab on 11 July 2014

14. Gomez, Jennifer (May 11, 2006). "Many firsts for 1Utama", p. 22. The Sun (Malaysia).

15. "Coal Energy". Retrieved, 2014 Available: http://www.realreturnenvironment.com/index.php?option=com_content&view=article&id=45&Itemid=73

APPENDICES

PROJECT GANTT CHART



APPENDIX A
VOLTAGE ATTEMPTS AND AVERAGE VOLTAGE DATA

TIME	RUN 1	RUN 2	RUN 3	AVERAGE VOLTAGE
0	0.00	0.00	0.00	0.00
0.05	0.00	0.00	0.00	0.00
0.1	0.00	0.00	0.00	0.00
0.15	0.00	0.00	0.00	0.00
0.2	0.00	0.00	0.00	0.00
0.25	0.00	0.00	0.00	0.00
0.3	0.00	0.00	0.00	0.00
0.35	0.00	0.00	0.00	0.00
0.4	0.00	0.00	0.00	0.00
0.45	0.00	0.00	0.00	0.00
0.5	0.00	0.00	0.00	0.00
0.55	0.00	0.00	0.00	0.00
0.6	0.00	0.00	0.00	0.00
0.65	0.00	0.00	0.00	0.00
0.7	0.00	0.30	0.00	0.10
0.75	0.00	0.04	0.00	0.01
0.8	0.00	0.34	0.00	0.11
0.85	0.00	0.83	0.00	0.28
0.9	0.00	0.98	0.07	0.35
0.95	0.01	0.64	0.03	0.22
1	0.01	0.36	0.00	0.13
1.05	0.01	0.06	0.00	0.02
1.1	0.53	0.00	0.00	0.18
1.15	3.84	0.00	0.00	1.28
1.2	7.20	0.58	0.01	2.60
1.25	9.86	3.36	0.17	4.46
1.3	12.25	6.09	1.69	6.67
1.35	14.01	8.17	4.02	8.73
1.4	15.27	9.57	5.97	10.27
1.45	15.99	10.11	7.35	11.15
1.5	16.43	11.76	12.88	13.69
1.55	16.85	12.37	13.69	14.30
1.6	17.55	13.43	14.22	15.06
1.65	18.22	14.90	14.93	16.01
1.7	18.65	18.11	15.61	17.46
1.75	18.85	18.14	16.43	17.81
1.8	18.95	18.12	17.22	18.10
1.85	19.12	18.07	17.49	18.23
1.9	19.15	18.01	17.61	18.26

1.95	19.17	17.77	17.81	18.25
2	19.10	17.44	17.84	18.12
2.05	19.09	17.13	18.02	18.08
2.1	18.99	16.74	18.04	17.92
2.15	18.88	16.27	18.18	17.78
2.2	18.76	16.07	18.38	17.74
2.25	18.62	16.24	18.53	17.80
2.3	18.63	16.16	18.51	17.77
2.35	18.87	15.90	18.48	17.75
2.4	19.20	15.67	18.56	17.81
2.45	19.35	15.60	18.71	17.89
2.5	19.37	15.69	18.80	17.95
2.55	19.48	15.84	18.80	18.04
2.6	19.53	15.91	18.79	18.07
2.65	19.19	15.94	18.67	17.93
2.7	18.60	16.27	18.51	17.79
2.75	17.52	16.70	18.46	17.56
2.8	15.06	16.88	18.46	16.80
2.85	12.31	16.91	18.20	15.81
2.9	10.63	16.90	17.84	15.12
2.95	9.18	16.57	17.41	14.39
3	7.75	15.60	16.23	13.19
3.05	6.37	13.98	16.02	12.12
3.1	4.28	11.86	13.01	9.72
3.15	1.68	9.82	11.50	7.66
3.2	0.13	5.81	9.84	5.26
3.25	0.00	0.00	6.38	2.13
3.3	0.00	0.00	5.09	1.70
3.35	0.00	0.00	4.05	1.35

APPENDIX B

CURRENT ATTEMPTS AND AVERAGE CURRENT DATA

TIME	CURRENT 1	CURRENT 2	CURRENT 3	AVERAGE CURRENT
0.35	0.00	0.00	0.00	0.00
0.4	0.00	0.00	0.00	0.00
0.45	0.00	0.00	0.01	0.00
0.5	0.00	0.00	0.02	0.01
0.55	0.00	0.00	0.09	0.03
0.6	0.00	0.02	0.18	0.07
0.65	0.00	0.06	0.25	0.10
0.7	0.00	0.11	0.29	0.13
0.75	0.00	0.14	0.31	0.15
0.8	0.00	0.18	0.34	0.17
0.85	0.00	0.21	0.35	0.19
0.9	0.00	0.22	0.36	0.19
0.95	0.00	0.24	0.36	0.20
1	0.00	0.25	0.35	0.20
1.05	0.00	0.25	0.36	0.20
1.1	0.00	0.26	0.37	0.21
1.15	0.00	0.27	0.40	0.22
1.2	0.00	0.26	0.41	0.22
1.25	0.00	0.27	0.42	0.23
1.3	0.00	0.28	0.42	0.23
1.35	0.00	0.28	0.43	0.24
1.4	0.00	0.31	0.44	0.25
1.45	0.00	0.34	0.45	0.26
1.5	0.02	0.34	0.45	0.27
1.55	0.08	0.37	0.46	0.30
1.6	0.15	0.37	0.45	0.32
1.65	0.23	0.39	0.46	0.36
1.7	0.31	0.41	0.47	0.40
1.75	0.37	0.44	0.49	0.43
1.8	0.41	0.44	0.51	0.45
1.85	0.45	0.44	0.51	0.47
1.9	0.50	0.43	0.53	0.48
1.95	0.53	0.44	0.54	0.50
2	0.58	0.44	0.55	0.52
2.05	0.61	0.47	0.55	0.55
2.1	0.64	0.49	0.54	0.55
2.15	0.66	0.50	0.54	0.56

2.2	0.69	0.52	0.53	0.58
2.25	0.68	0.53	0.53	0.58
2.3	0.67	0.54	0.52	0.58
2.35	0.69	0.53	0.51	0.58
2.4	0.72	0.51	0.52	0.58
2.45	0.72	0.49	0.54	0.59
2.5	0.73	0.49	0.55	0.59
2.55	0.74	0.49	0.56	0.60
2.6	0.74	0.48	0.58	0.60
2.65	0.74	0.47	0.59	0.60
2.7	0.72	0.47	0.61	0.60
2.75	0.71	0.47	0.61	0.60
2.8	0.66	0.50	0.62	0.59
2.85	0.63	0.50	0.63	0.59
2.9	0.63	0.50	0.64	0.59
2.95	0.62	0.50	0.63	0.58
3	0.62	0.51	0.62	0.58
3.05	0.63	0.53	0.64	0.60
3.1	0.62	0.54	0.65	0.60
3.15	0.62	0.54	0.65	0.60
3.2	0.61	0.55	0.66	0.60
3.25	0.61	0.54	0.65	0.60
3.3	0.59	0.53	0.63	0.59
3.35	0.60	0.53	0.61	0.58
3.4	0.59	0.52	0.59	0.57
3.45	0.59	0.51	0.58	0.56
3.5	0.60	0.51	0.58	0.56
3.55	0.62	0.50	0.56	0.56
3.6	0.62	0.50	0.54	0.55
3.65	0.61	0.49	0.54	0.55
3.7	0.62	0.50	0.55	0.55
3.75	0.62	0.52	0.55	0.56
3.8	0.62	0.53	0.55	0.57
3.85	0.63	0.53	0.54	0.56
3.9	0.64	0.53	0.52	0.56
3.95	0.65	0.54	0.52	0.57
4	0.64	0.54	0.51	0.56
4.05	0.63	0.52	0.47	0.54
4.1	0.62	0.50	0.44	0.52
4.15	0.61	0.50	0.40	0.50
4.2	0.59	0.49	0.35	0.48
4.25	0.55	0.50	0.29	0.45
4.3	0.52	0.50	0.22	0.41
4.35	0.51	0.49	0.19	0.40
4.4	0.51	0.48	0.13	0.37

4.45	0.46	0.45	0.06	0.32
4.5	0.40	0.37	0.01	0.26
4.55	0.42	0.30	0.00	0.24
4.6	0.44	0.27	0.00	0.23
4.65	0.43	0.31	0.00	0.25
4.7	0.37	0.34	0.00	0.23
4.75	0.31	0.33	0.00	0.21
4.8	0.25	0.33	0.00	0.19
4.85	0.18	0.31	0.00	0.16
4.9	0.12	0.30	0.00	0.14
4.95	0.07	0.29	0.00	0.12
5	0.01	0.25	0.00	0.09
5.05	0.00	0.22	0.00	0.07
5.1	0.00	0.17	0.00	0.06
5.15	0.00	0.12	0.00	0.06
5.2	0.00	0.06	0.00	0.03

APPENDIX C
AVERAGE VOLTAGE, CURRENT AND POWER DATA

TIME	AVERAGE VOLTAGE	AVERAGE CURRENT	AVERAGE POWER
0	0.00	0.00	0.00
0.05	0.00	0.00	0.00
0.1	0.00	0.00	0.00
0.15	0.00	0.00	0.00
0.2	0.00	0.00	0.00
0.25	0.00	0.00	0.00
0.3	0.00	0.00	0.00
0.35	0.00	0.00	0.00
0.4	0.00	0.00	0.00
0.45	0.00	0.00	0.00
0.5	0.00	0.01	0.00
0.55	0.00	0.03	0.00
0.6	0.00	0.07	0.00
0.65	0.00	0.10	0.00
0.7	0.10	0.13	0.01
0.75	0.01	0.15	0.00
0.8	0.11	0.17	0.02
0.85	0.28	0.19	0.05
0.9	0.35	0.19	0.07
0.95	0.22	0.20	0.04
1	0.13	0.20	0.03
1.05	0.02	0.20	0.00
1.1	0.18	0.21	0.04
1.15	1.28	0.22	0.28
1.2	2.60	0.22	0.58
1.25	4.46	0.23	1.03
1.3	6.67	0.23	1.56
1.35	8.73	0.24	2.07
1.4	10.27	0.25	2.57
1.45	11.15	0.26	2.94
1.5	13.69	0.27	3.73
1.55	14.30	0.30	4.32
1.6	15.06	0.32	4.89
1.65	16.01	0.36	5.77
1.7	17.46	0.40	6.94
1.75	17.81	0.43	7.70
1.8	18.10	0.45	8.15
1.85	18.23	0.47	8.53

1.9	18.26	0.48	8.82
1.95	18.25	0.50	9.18
2	18.12	0.52	9.51
2.05	18.08	0.55	9.87
2.1	17.92	0.55	9.94
2.15	17.78	0.56	10.03
2.2	17.74	0.58	10.31
2.25	17.80	0.58	10.34
2.3	17.77	0.58	10.22
2.35	17.75	0.58	10.26
2.4	17.81	0.58	10.39
2.45	17.89	0.59	10.47
2.5	17.95	0.59	10.58
2.55	18.04	0.60	10.80
2.6	18.07	0.60	10.86
2.65	17.93	0.60	10.74
2.7	17.79	0.60	10.66
2.75	17.56	0.60	10.48
2.8	16.80	0.59	9.97
2.85	15.81	0.59	9.26
2.9	15.12	0.59	8.88
2.95	14.39	0.58	8.40
3	13.19	0.58	7.71
3.05	12.12	0.60	7.25
3.1	9.72	0.60	5.87
3.15	7.66	0.60	4.63
3.2	5.26	0.60	3.18
3.25	2.13	0.60	1.27
3.3	1.70	0.59	1.00
3.35	1.35	0.58	0.78
3.4	0.00	0.57	0.00
3.45	0.00	0.56	0.00
3.5	0.00	0.56	0.00
3.55	0.00	0.56	0.00
3.6	0.00	0.55	0.00
3.65	0.00	0.55	0.00
3.7	0.00	0.55	0.00
3.75	0.00	0.56	0.00
3.8	0.00	0.57	0.00
3.85	0.00	0.56	0.00
3.9	0.00	0.56	0.00
3.95	0.00	0.57	0.00
4	0.00	0.56	0.00
4.05	0.00	0.54	0.00
4.1	0.00	0.52	0.00

4.15	0.00	0.50	0.00
4.2	0.00	0.48	0.00
4.25	0.00	0.45	0.00
4.3	0.00	0.41	0.00
4.35	0.00	0.40	0.00
4.4	0.00	0.37	0.37
4.45	0.00	0.32	0.32
4.5	0.00	0.26	0.26
4.55	0.00	0.24	0.24
4.6	0.00	0.23	0.23
4.65	0.00	0.25	0.25
4.7	0.00	0.23	0.23
4.75	0.00	0.21	0.21
4.8	0.00	0.19	0.19
4.85	0.00	0.16	0.16
4.9	0.00	0.14	0.14
4.95	0.00	0.12	0.12
5	0.00	0.09	0.09
5.05	0.00	0.07	0.07
5.1	0.00	0.06	0.06
5.15	0.00	0.06	0.06
5.2	0.00	0.03	0.03
5.25	0.00	0.01	0.01
5.3	0.00	0.00	0.00