DESIGN & FABRICATION OF VERTICAL TURBINE FOR RURAL MICRO HYDROELECTRIC GENERATION

BY

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BACHELOR OF ENGINEERING (HONS)

MECHANICAL ENGINEERING

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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BACHELOR OF ENGINEERING (Hons)
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Approved by,

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(MOHD FAIZAIRI B MOHD NOR)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
MAY 2012

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.

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IKA FARIKHA SYAZWANI BT ABD RAHMAN

ABSTRACT

Increasing demands of electricity nowadays has put to the tremendous developments and innovation of hydro turbine. In remote area, limited electricity sources are one of the reasons for developing a small scale of hydro turbine. With this small scale, it has the most cost effective energy sources and provides a clean electricity generation. A zero head water turbine has been selected as a source for electricity in off grid rural area where the construction of dam is not required. This paper discusses the experiment of Design & Fabrication of Vertical Turbine for Rural Micro Hydroelectric Generation. It consists of Background Study of the project, Problem Statement, Objective, Scope of Study, Literature Review for the relevance topic, Methodology and final Result, Conclusion and Recommendations to improvise the experiment. In this project, the author design and fabricate the vertical crossflow run river turbine based on the relevant parameters and determine the power output that can be produced from the turbine. Basically, the scope of study is to get the possible power output, minimum of 1KW based on all the possible information about the river and the parameters of the turbine. In this experiment, design of the turbine blades has been change from semicircular to flat blades. This is due to fabrication problem that might affect the accuracy of the power output. However, the power produced is very limited due to some circumstances and fabrication problems. The minimum power produced is 3.2 volt when the velocity is about 2m/s. At the end of this research, several recommendations have been made to improve the power that could be generated from the turbine.

ACKNOWLEDGEMENTS

I would like to thank the various people involved in making this final year project a success:

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1.0 INTRODUCTION

1.1 Background Study

The hydropower plant can be divided into various types according to its capacity and power consumes. Hydropower is considered as renewable energy as the water cycle is endless. It is powered by the kinetic energy of water and then converts into electricity by generators and turbines.

Most of the hydropower plants are large power consumes due to high electricity demands. Large power supply which requires dams affects environment and people lives in rural area. Small capacity hydro plant suits for small village residents needs. It is environmental friendly, does not need dams and most importantly, lower construction and maintenance cost.

To be more specific, the experiment applies at Orang Asli Village, Grik, Perak. Crossflow microhydro turbine was chosen to provide extra source of electricity. Currently, the loction of project are using solar power system and diesel generator as their main source. High cost for diesel through entire year and low efficiency for solar cells lead to seek another visible and viable alternative.

Crossflow micro turbine is a power system that converts kinetic energy to electrical energy. Usually, a turbine build considers a penstock to transfer the water inlet to the turbine. Specifically, most of the projects are considering 'head' to increased the velocity of the water inlet. However, in this case, the experiment only focuses on zero head for the turbine. This will protect the environment as the location of the specific area is the government's indigenous placement programme. The experiment is based on the off grid area, for the small capacity needed which is about 100 residents. Thus, power supply needed is lower which is about 2KW per person. Studies have been done to determine the velocity of the river and the amount of energy needed for daily used. Based on this, a vertical turbine has been designed based on the specific requirements.

As the velocity of the river may vary from time to time, the water inlet of the turbine must at least meet the minimum velocity to produce electricity. A specific design being produced to ensure the electric power still can be generated in very low velocity of inlet water.

1.2Problem Statement

Living in a rural area is away from development and facilities such as electricity and clean water resources. Government takes an effort to make sure citizens in rural area are having equal rights and development as citizens in urban area.

People lives in rural area, focused in Sekolah Kebangsaan Sungai Tiang, Gerik, Perak area lives with insufficient electricity supply. There is no grid connection in the Orang Asli Village due to environmental effects and huge amount of construction cost.

Currently, they are using solar power system and diesel generator as an electric supply for daily activities. There are circumstances that lead to problems when using those power supplies. Solar panel system that had been installed in Sekolah Kebangsaan Sungai Tiang, Gerik is not be able to fully support the school. This also is caused by the lower capacity of the cells. Another problem, solar panel system is less effective as its efficiency only about 10 per cent.

Another electric supply that they had been using until now is diesel generator. This supply source gives consistence power of electricity. However, the generator used can only supply not more than 1000W per day. Problem arises when electricity is only available from 7 am until 7 pm only. Furthermore, high cost for diesel currently RM 1.80 per litre also limits the residents to use electric power wisely. On top of that, transportation cost to transfer diesel from sources to village also counts into account.

Another source for electricity needs to be implemented to improve this situation. Renewable energy is very suitable for this case. Run River as a natural resource acts as a medium to generate electricity for the small power consumption.

1.3 Objective

1) To design and fabricate a vertical zero head of micro turbine that suits the condition area. Design condition must suits the velocity of the flowing water and possible ways to get higher power output of the turbine.
2) To fully utilize the natural resources such as river to generate extra electricity.

1.4 Scope of Study

The system does not require a dam. It uses run river water turbine that is no head application. A hydro system that builds can generate electricity from kinetic energy to electric energy. Power output is used for Sekolah Kebangsaan Sungai Tiang area. Estimated loading demand is 100 residents per 100 watt needed. Meaning, this power produced can supply basic need for household such as, lighting and a refrigerator. Cross flow water turbine has been selected for this project as it only suited for small scale of power application typically less than 100KW [1]

2.0 Literature Review

The hydro power plant can be divided into several types and it is classified according to the size of electrical power produced. Based on this, the installation of hydropower can be classified onto different ways such as, by effective head of water, capacity of the power output, type of turbine used and the location of the power plant.

2.10 Type of Turbine

There are two types of turbine, reaction turbine and impulse turbine. The type of turbine is selected based on the height of the standing water (head) and volume of the water available. Reaction turbine converts potential energy in pressurized water to mechanical energy. Usually, the reaction turbine used for sites with lower head and high flow rate. Unlike Impulse turbine, it converts kinetic energy from jet water to the mechanical energy. Generally, it is suitable for low speed of water supply and high head condition.

Both impulse and reaction turbines can be classified into various names for example, Francis turbine, Kaplan turbine, Pelton turbine and cross-flow turbines. All these turbines are differ in type, size, application and power output as shown in Table 1.

Power	**Class**
>10MW	Large
<10 MW	Small
< 1MW	Mini
<100 KW	Micro
<5 KW	Pico

Table 1: Classification of hydro power [2]

Various turbines types and applications also can be classified based on available head and flow rates as shown in Figure 1 and Table 2 below.

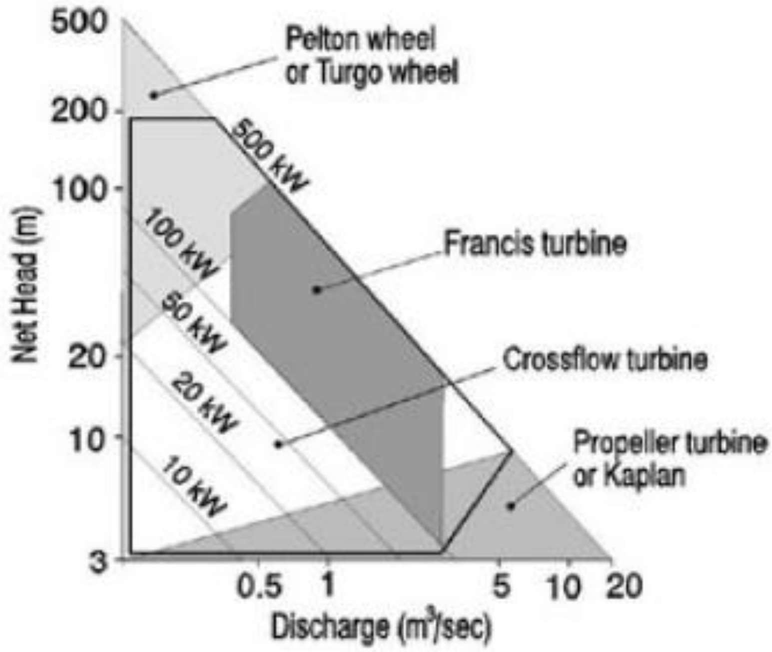


Figure 1: Head Flow Ranges of Small Hydro Turbines [3]

Turbine	**Head (Pressure)**		
	Low	**Medium**	**High**
Impulse	Pelton Turgo	Crossflow Pelton	Crossflow
Reaction	-	Francis Pump	Propeller

Table 2: Application of Turbines [4]

2.12 Crossflow Micro Turbine

With high demands of electricity especially for heavy industries and household needs, large power supplies needed to support these rapidly increasing demands. However, these large hydro plants lead to environmental issues as the construction of dams destroy the ecosystem of flora and fauna.

In this project, focus will be on crossflow micro turbine. The crossflow water turbine allows the water to flow through the blade twice. The first pass is when the water flow from the outside of the blade to the inlet. The second pass is from the inlet to the outlet of the turbine. To be specific, the water inlet of the turbine enters at the angle of α and velocity v_1 with tangent to the periphery. β_1 is the angle between forward direction of the two latter. [5]

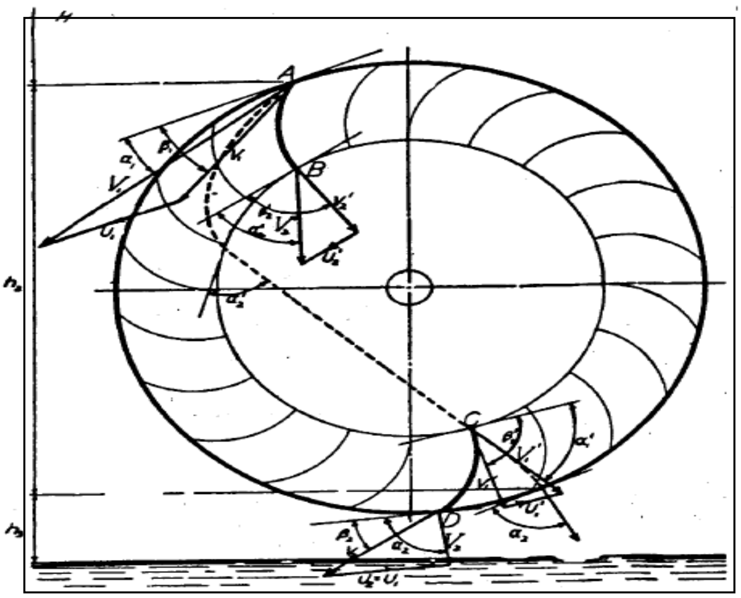


Figure 2: The Banki Water Turbine , C.A Mackmore , Fred Merryfield, 1949

Cross flow micro turbines can operate with head between 5m to 200 m. The system allows the water to pass through the runner and crosses it two times before leaving the turbines [6]. The simple design makes cross flow turbine easy to maintain and has lower cost compared to other turbines. The capacity for micro turbines is smaller compared to other hydro power plants turbines. With this smaller scale of turbine it is the best solution for small range of power applications. This system does not required dams to generate electricity and more importantly has low investment cost and reliable maintenance cost. This system depends on necessary flow rate of run river flow rate to convert from kinetic energy to electric energy. Thus, this system is environmentally safe for small scale of power applications that not more than 1000KW.

Although run river water turbine is an alternative method due to its lower operating cost, it has low efficiency compared to other larger scale of turbines. The head loss between the downstream level and the runner lowered the effectiveness of the turbine.

A project at Taratak, Indonesia is one of the example that using small scale of hydro turbine to generate electricity. It has been successfully operates at below 5.5m head and 240 L/s discharge rate [7]. Another project is in Cameroon, a system that design 10m head and 92.61L/s flow rate used to provide 24V DC system with only 5Kw capacity [8].

Normally, power generation at rural areas are provided by solar system and diesel generator as their electric supply for daily use. This small hydropower plant ensure the residents to light up in nights and used for basic daily activities. However, operating hours for this system is limited plus, diesel cost and its transportation are inconvenient to buy. The lower efficiency of solar cells that can only generate 10 per cent of the electric gives another reason to find a better alternative for this problem. In rural Kenya, a comparison between hydro power and solar power has been made to evaluate the power in off grid electricity area [9]. For the same reason, similar assessment was made at Uruguay for bigger micro hydro (100 kW) turbine at the off- grid electrification [10].

In the research paper of Parametric Study on Performance of Cross Flow Turbine by C.B Joshi, V. Seshadri and S.N. Singh, it stated that the efficiency of turbine increase with increase in blade number, nozzle entry arc and head. The scope of study for this research is to evaluate the performance of the turbine for medium to low head by varying the number of blades from 8-30 and nozzle entry from 23º to 36º. [10]

The first experiment is to evaluate between number of blade and the maximum efficiency of the turbine. The efficiency of the turbine is increasing up to 80% as the number of blade increasing from 4 to 32 blades. The second experiment is to compare the relationship between the arc angle of water inlet and the maximum efficiency of the turbine as the head of the turbine is increased. The highest efficiency is around 60% when the arc angle is 38º.

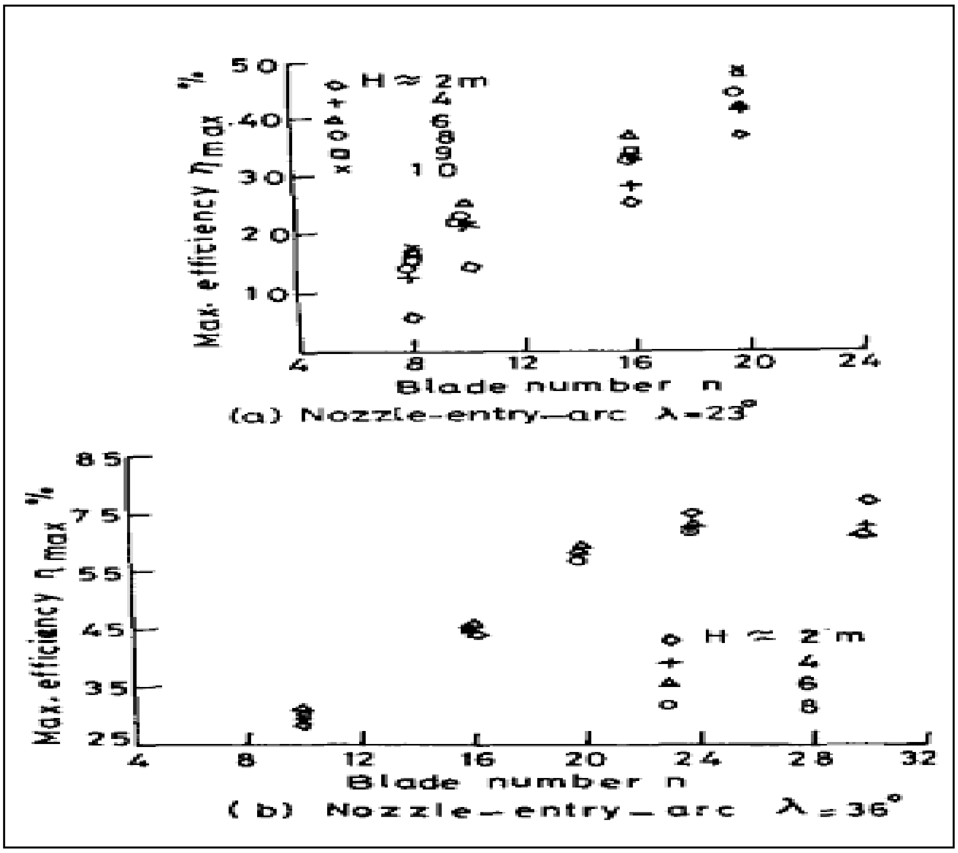


Figure 3: Effect of Blade number on Max. Efficiency of Cross Flow Turbine

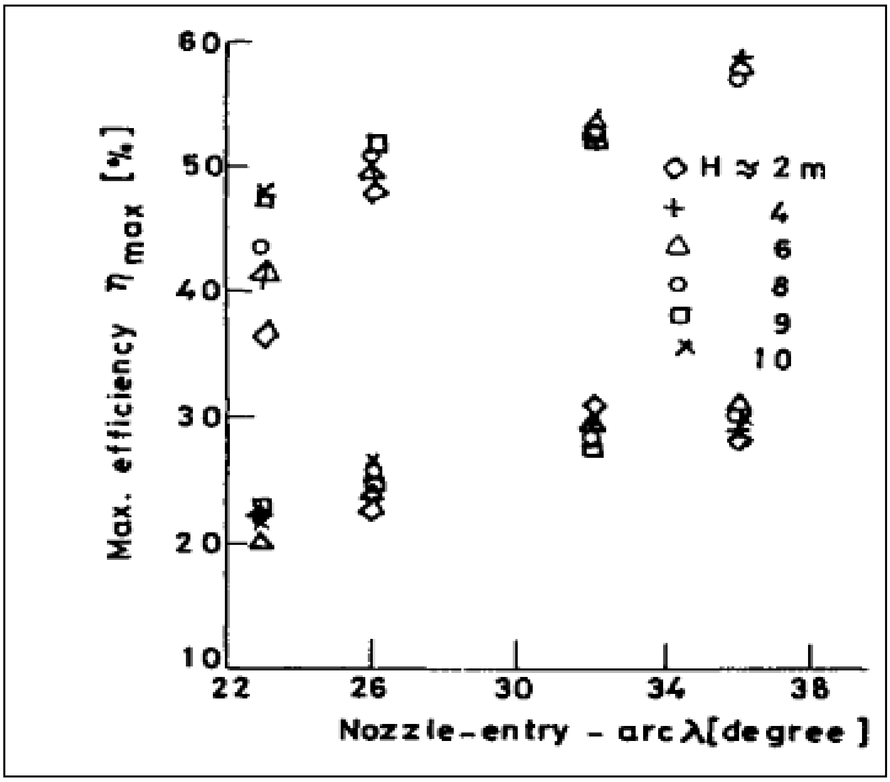


Figure 4: Effect of Nozzle Entry Arc on Max. Efficiency of Cross Flow Turbine

Research that has been conducted is become the benchmark for this project. Based on these criteria, micro hydro power system are more cost effective and viable compared to solar panel system. This is only applicable if the project location near the water resources. Thus, small scale micro turbine should be considered as a medium to generate electricity. Selection criteria of turbine need to be clarified to suit the head mad flow rate as the depth of river might be differ.

From the research paper of Design and Manufacture of Micro Zero Head Turbine for Power Generation by HITEX University Taxilia, Pakistan found that the power produce is approximately 50 watt when the water speed is 1.2 m/s. [11]

2.13 DC Motor

A DC motor is an electric motor that runs the direct current which is from rechargeable batteries. The basic induction of DC motor has two components which are rotor and stator. Rotor is produced from the principle of electromagnetic induction and it rotates. Stator is a part of motor that is stationary. A stator in a motor is a wire coil of copper or aluminium.

Theoretically, current flows through the stator of windings which surrounds the rotor. The current that flow will produce a constant rotating magnetic field in the stator. This magnetic field induces a current flow in the rotor. The induced current of the rotor is the produced its own magnetic field [12]. Opposite direction of magnetic field produced in the rotor and stator make them repel each other. Continuous repulsion will transform into electric power.

The example of the basic concept of electric DC motor is bicycle dynamo. The magnet inside the coil with the north pole effecting one half of the coil and the south pole effecting the other half of the coil. [13]

When the electric current passes through a coil, the magnetic force produce a torque which turn the DC motor. The magnetic force act perpendicular to the wire and the magnetic field. Then the commutator reverses the current each half revolution. This is to keep the torque turns the coil in the same direction. This is how the magnetic field is directed from North Pole to south pole. [14]

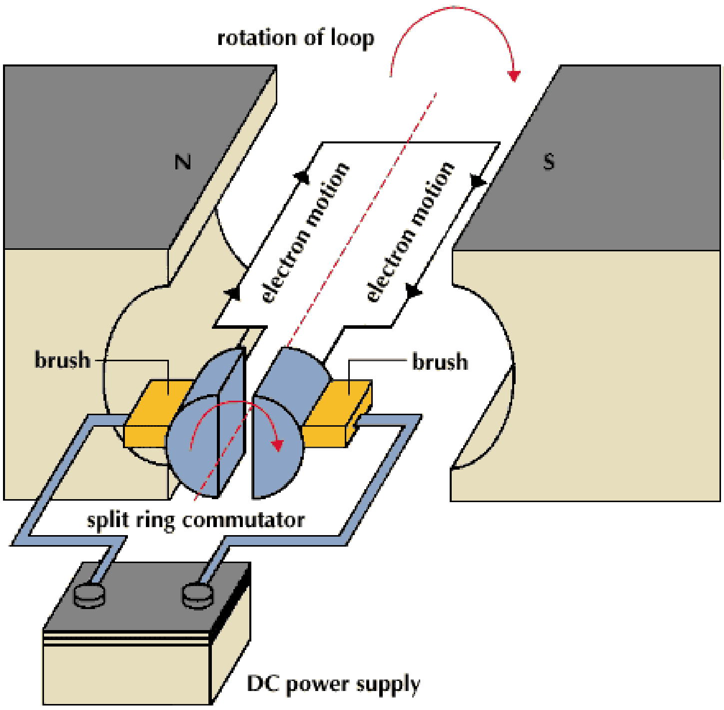


Figure 5: Operation of DC Motor

Interaction between coils and magnets depends on various conditions. They are the number of coils needed, size of the coils, the magnetic strength and the size of wire used. All these conditions will affect the total output power produced. From the Faraday Law,we can find out the number of turns of the windings.

N = -1 * (-V/ change in ((tesla * area meters squared)/ seconds))

3.0 Methodology

3.1 Research Methodology

Test Site Location

The kinetic energy of the flowing water is being converted to electric energy by the turbine. A site within Seri Iskandar River was selected for location study. A natural run river with continuous water flow throughout the year used as standard condition for this study. By assuming the worst case scenario for this project is 50% efficiency, power available from the river is determined by using equation [15]:

$$P = \frac{1}{2}\eta\rho A v^3 \qquad \text{.................................(1)}$$

Where

η= Turbine efficiency

ρ= density of water

A= area of the water attack

V= velocity of the river

Next, the mass flow rate of the river can be determined by using the equation:

$$\text{Mass Flow Rate} = \text{Volume flow rate} \times \rho_{water} \times \text{specific gravity of water}$$

3.2 Project Activities

3.2.1 Vertical Turbine Micro Hydroelectric

Crossflow water turbine consists of two major parts. They are shaft and a turbine runner. The runner is build up of two parallel circular disks jointed together at the shaft with a series of curves blades [16]. The water inlet to the turbine strikes twice of the blades before could discharge at the outer of the blades. The kinetic energy from the moving water will be converted to electric energy. In this case of study, vertical turbine has been chosen. Based on the volume flow rate of the water and the power available from the experiment's location, number of blades of the turbine, diameter of the rotor can be design to meet the requirements.

Using CATIA design software, draft designs for vertical turbine have been produced. Further improvement on that design had been made and optimum design is produced.

3.2.2 Design of Blades

The design of blades assumes to be semi circular and eight numbers of blades in order to get maximum flow rate entering from the river. By using semi circular blades, it will give the highest velocity profile on the surface and decreases as it goes downward. Besides, semi circular shape used to allow more flow of water to enter bucket as compared to one that using flat blade. [17]

3.2.3 Mock- Up

Before fabrication of crossflow micro turbine has been made, mock-up process was done to view the design performance in small scale. For mock-up purpose, cardboard and papers has been used to get the idea of the turbine. In this process, the diameter of the shaft is 4cm. Length of the blade is 7.5 cm and 8 blades have been used.

Figure 6: Mock-Up Turbine

3.2.4 Fabrication

In fabrication process, the best material chosen is Aluminium for blades and the shaft. Aluminium 0.2 cm thickness has been chosen for the blades and the disks. For shaft, a cylinder made of Aluminium, diameter of 2 cm is being used for this project.

Theoretically, semi circular blades are chosen for crossflow micro turbine. In the fabrication process, problems occur when the circular blades made using folding machine are not symmetry. This will result to the lower power produced.

Figure 7: Semi Circular Blades

Theoretically, semi circular blade will produced higher power output. Due to this fabrication problem, straight blade is being chosen. 8 blades are being used instead of 6 blades to increase the power output.

Figure 8: Straight Blades

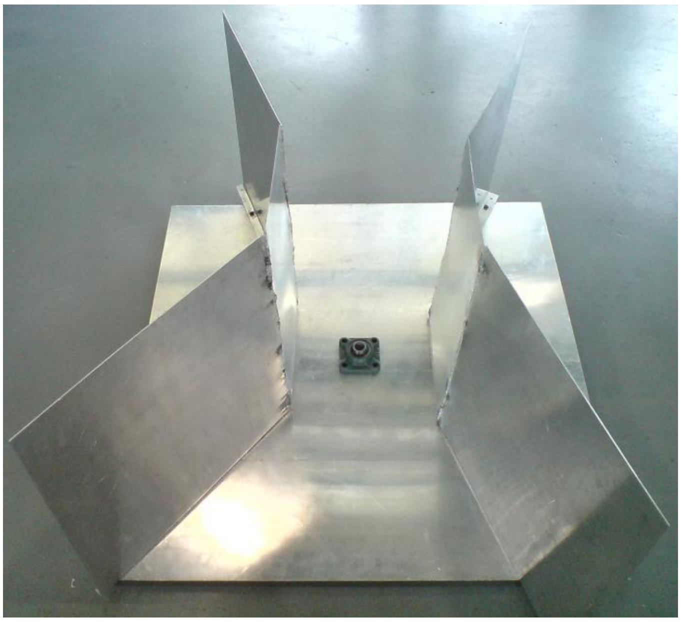


Figure 9: Housing of the Turbine

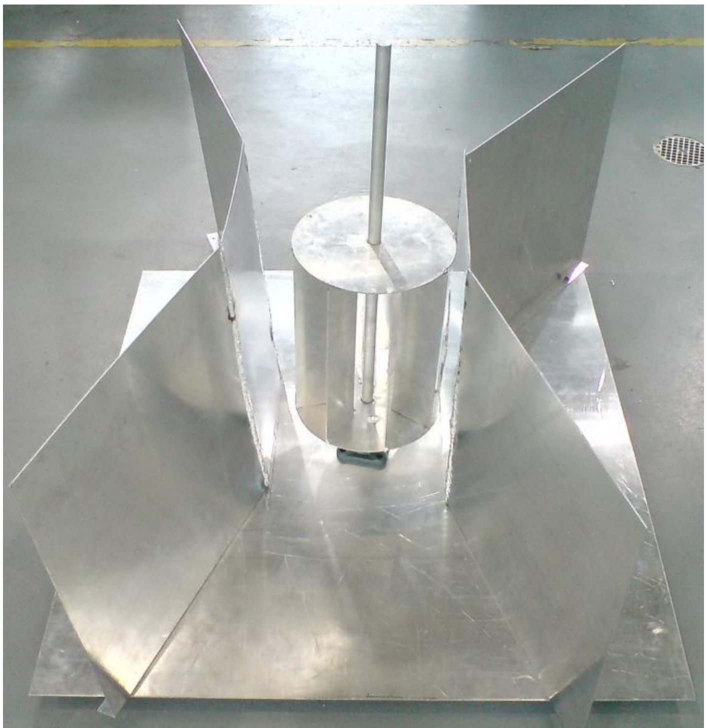


Figure 10: Housing Attached with Vertical Turbine

3.2.5 Testing

Testing process done to test the turbine whether it functioning well or not. In this process, a modelling testing is being conducted by using air instead of using water. The power output of the turbine is being measured and being compared to the theoretical that had been calculated. Any changes or irrelevant data is being interpreted and discuss.

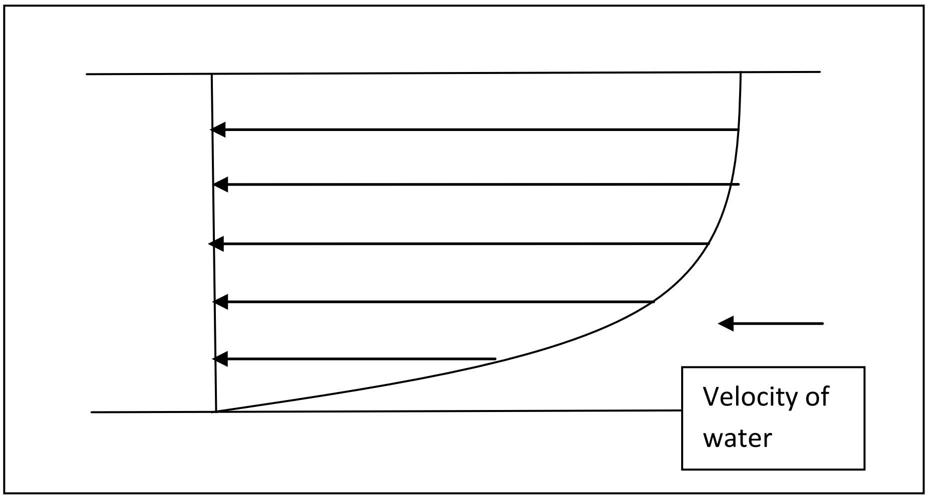


Figure 11: Velocity Profile of water [18]

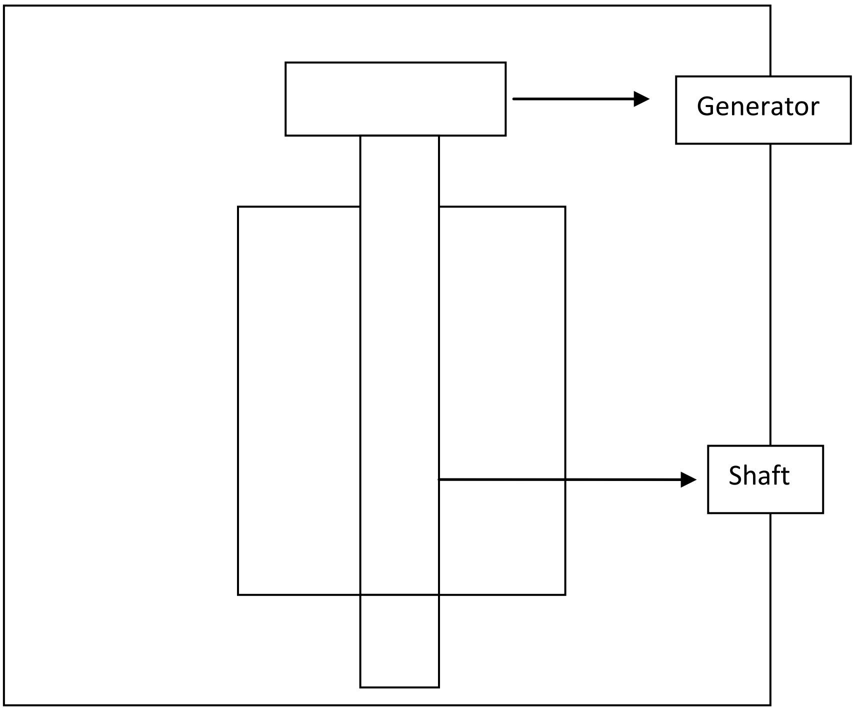


Figure 12: Sketch of Vertical Turbine

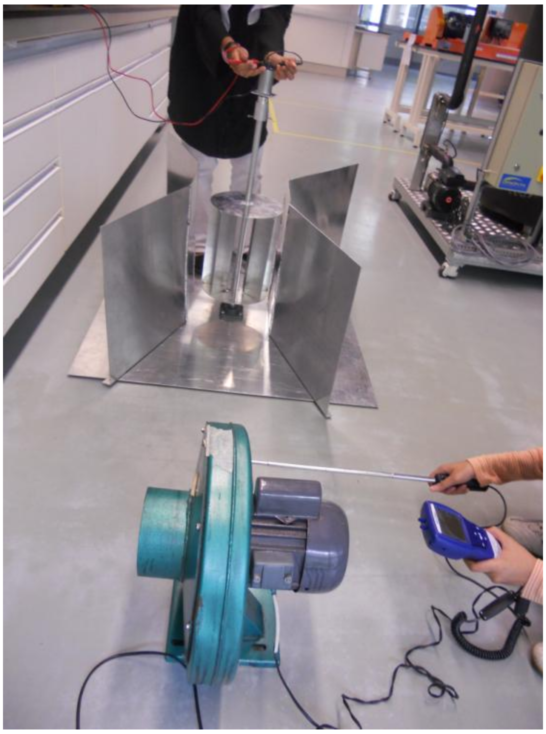


Figure 13: Testing Process

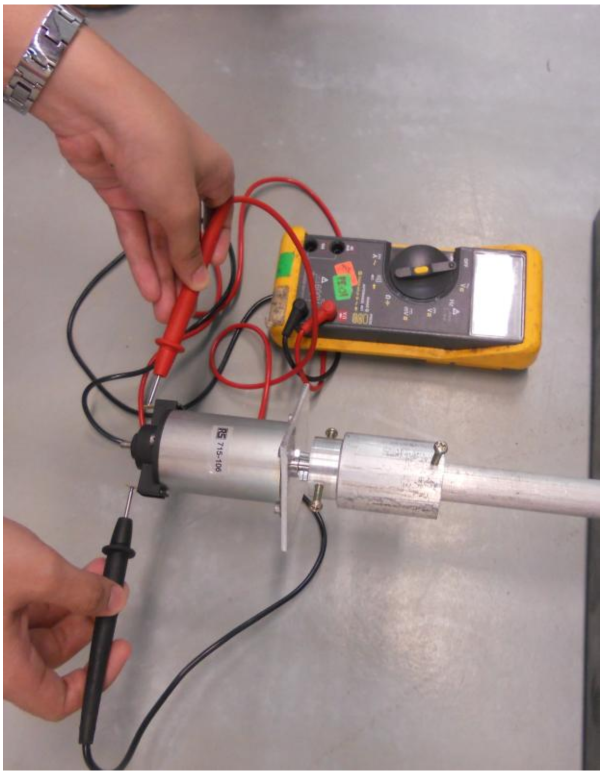
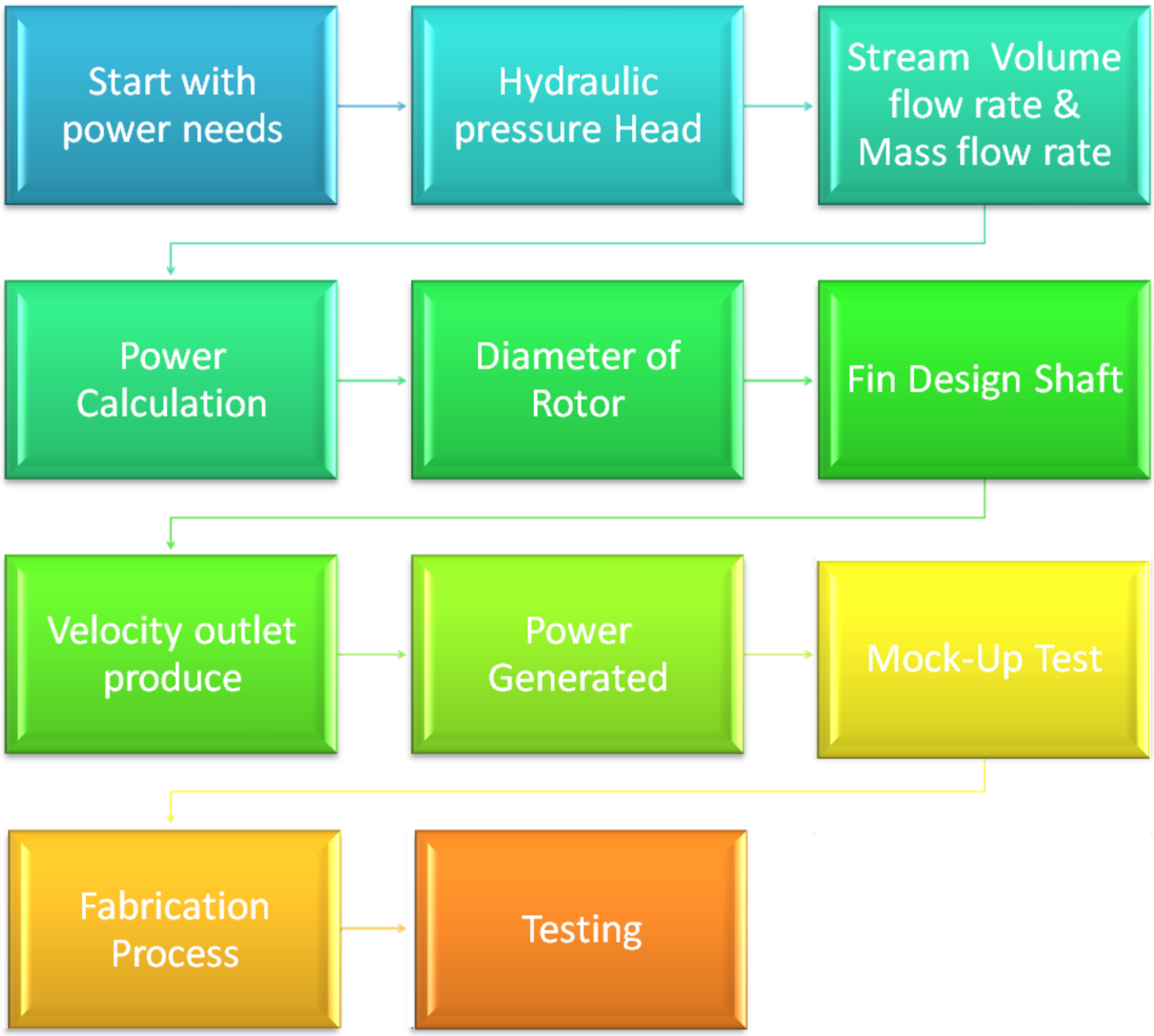
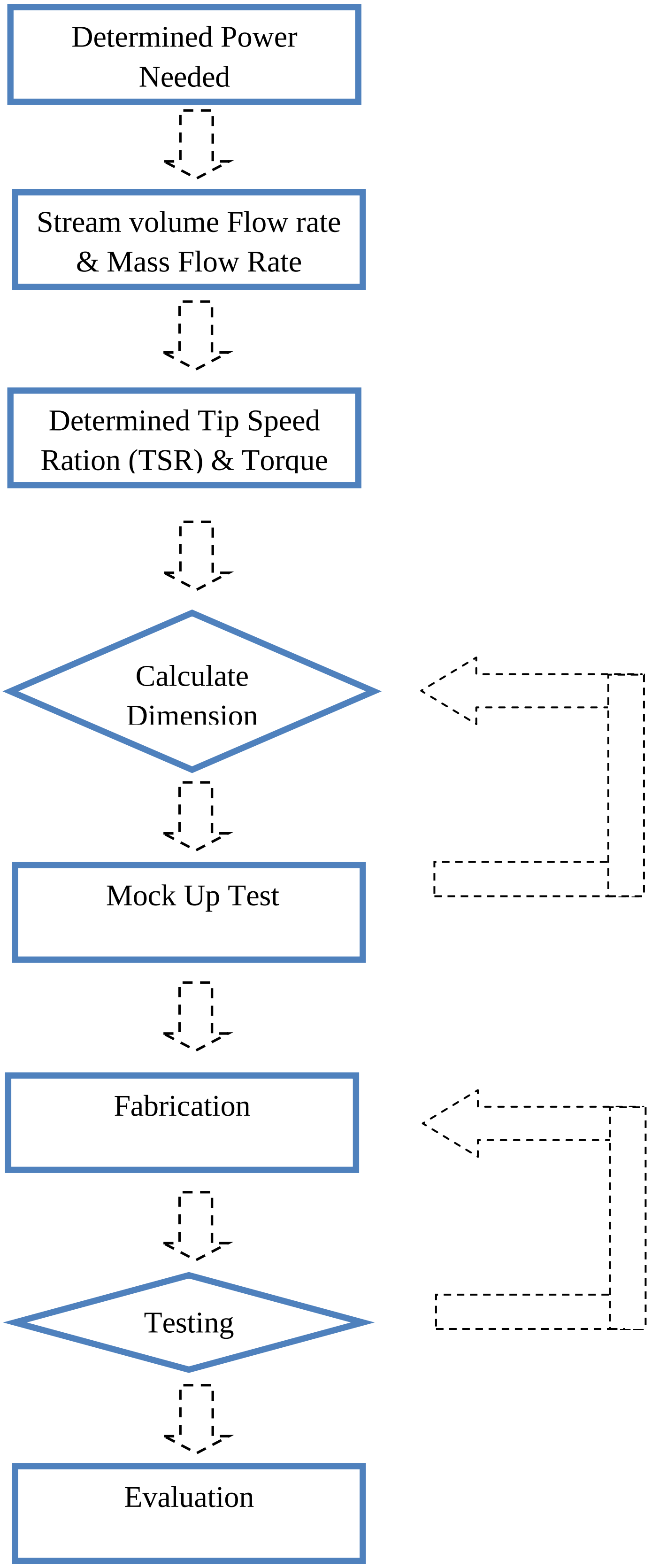


Figure 14: Digital Multimeter To Measure Voltage

3.2 Key Milestone



3.3 Flow Chart



3.4 Tools

1. **Equipments:**

a) Generator

b) Aluminium 10 mm, 20 mm

c) Cylinder Diameter = 20mm

d) Neodynium Magnet N48

e) Vertical Bearing

f) Copper Coil

g) Perspex

h) Epoxy

i) Digital Multimeter

2. **Software:**

a) CATIA

4.0 Result and Discussion

4.1.0 Calculation

4.1.1 Tip Speed Ratio (TSR)

Designing the turbine blade is very important to determine the power output of the turbine. For designing process, Tip Speed Ratio (TSR) must be find before the blade radius can be calculated using these formulas [19].

$T = (TSR.\ \acute{\omega}_{water}) / R$

$P = T\acute{\omega}$

$TSR = V_{linear\ velocity\ of\ tip\ blade} / V_{river}$

Tip Speed Ratio(TSR) is the ratio of the speed of the blade at the its tip and the speed of the river water. Tip Speed Ratio is very important in the water turbine blade. If the rotor of the turbine spins too slowly, most of the water will pass straight through the gap between the blades, therefore giving it no power. But if the rotor spins too fast, the blades will blur and act like a solid wall to the water [20]. That is the reason why TSR plays an important role to get the maximum power output.

Below is the calculation for the Tip Speed Ratio (TSR), blade radius, and the theoretical power output based on the various speed of velocity at the tip of the blade.

Velocity of the Blade (m/s)	Velocity of water (m/s)	TSR	Angular velocity (rad/s)	Power(W)	Torque(N.m)	Blade radius(M)	Angular velocity(rpm)
3.5	3	1.166667	23.97260274	20.25	0.844714286	0.146	228.8918148
3.6	3	1.2	24.65753425	40.5	1.6425	0.146	235.431581
3.7	3	1.233333	25.34246575	60.75	2.397162162	0.146	241.9713471
3.8	3	1.266667	26.02739726	81	3.112105263	0.146	248.5111132
3.9	3	1.3	26.71232877	101.25	3.790384615	0.146	255.0508794
4	3	1.333333	27.39726027	121.5	4.43475	0.146	261.5906455
4.1	3	1.366667	28.08219178	141.75	5.047682927	0.146	268.1304117
4.2	3	1.4	28.76712329	162	5.631428571	0.146	274.6701778

4.3	3	1.433333	29.45205479	182.25	6.188023256	0.146	281.2099439
4.4	3	1.466667	30.1369863	202.5	6.719318182	0.146	287.7497101
4.5	3	1.5	30.82191781	243	7.884	0.146	294.2894762
4.6	3	1.533333	31.50684932	283.5	8.998043478	0.146	300.8292423
4.7	3	1.566667	32.19178082	324	10.06468085	0.146	307.3690085
4.8	3	1.6	32.87671233	364.5	11.086875	0.146	313.9087746
4.9	3	1.633333	33.56164384	405	12.06734694	0.146	320.4485408
5	3	1.666667	34.24657534	445.5	13.0086	0.146	326.9883069

Table 3: Calculation for Theoretical Power and Torque

4.12 Design of the Vertical Turbine

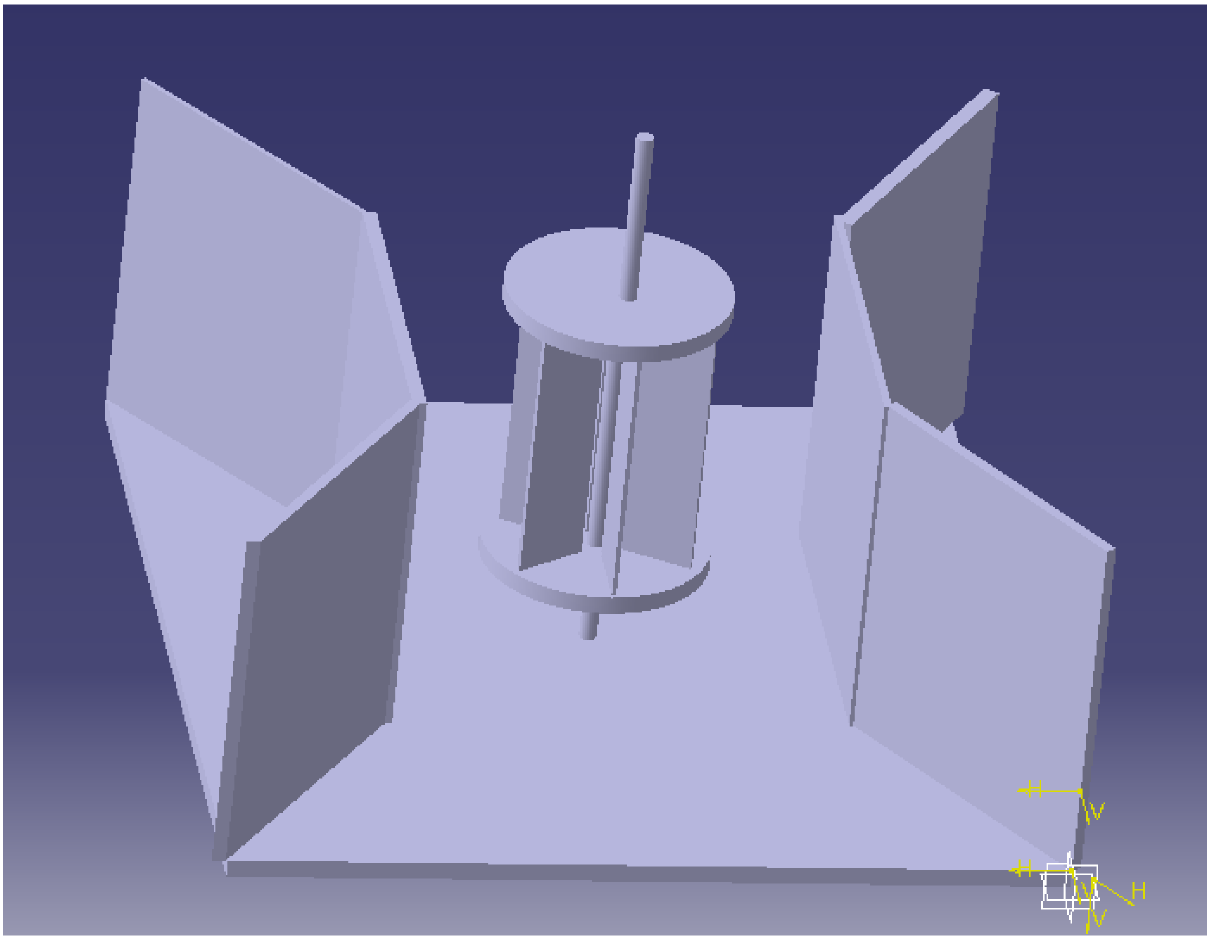


Figure 15: Design of the Turbine with the Housing

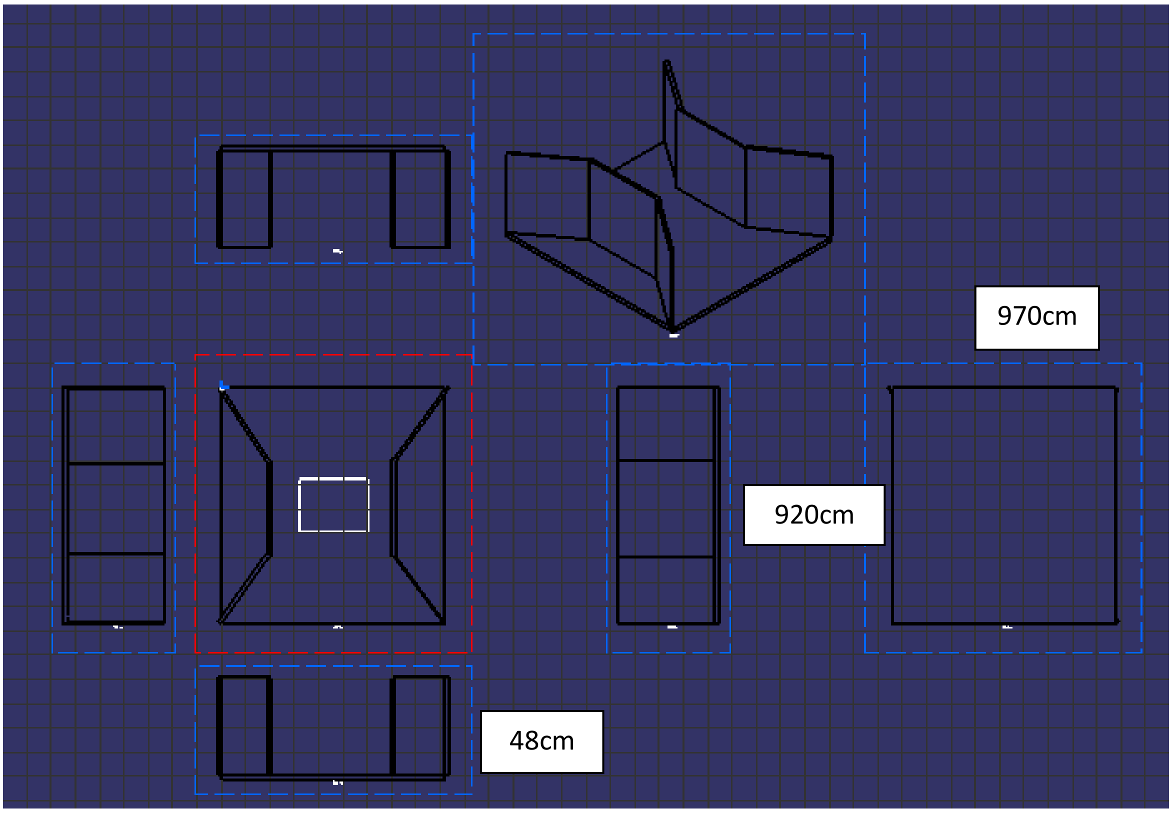


Figure 16: Exploded View for Housing

4.1.3 Material Selection

For the current design, Aluminium was chosen instead of Steel. Following are the properties for Aluminium [21]:

Density: 2.7g/cm³

Melting Point: 660.32ºC

Boiling Point: 2519ºC

Young Modulus: 68-88.5 GPa

Tensile Strength: 75-360 MPa

Advantages:

- Very light weight
- Ductile material
- 100% recyclability
- High corrosion resistance

4.1.4 Fabrication of Vertical Turbine

Figure 17: Blades of Semi Circular

Figure 18: Blades of Flat Blades

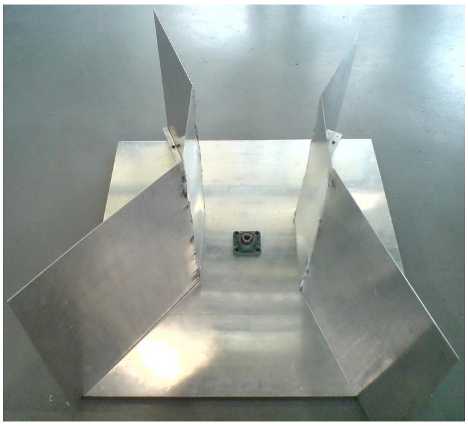


Figure 19: Housing of The Vertical Turbine

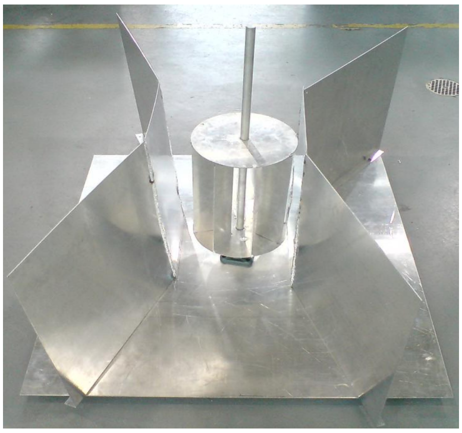
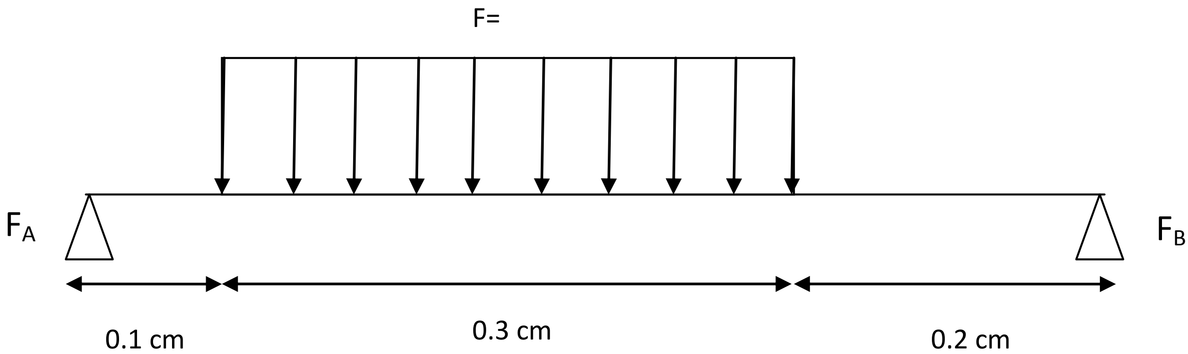


Figure 20: Housing Attached with Turbine

Figure 21: Vertical Turbine, Housing with the Generator

4.1.5 Shaft without Bearing



Power = (F X A)*((TSR x V) / R)

At constant velocity of water 3 m/s,

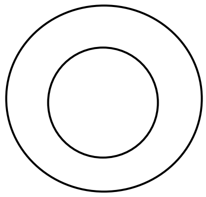
1620 W = (F x 0.12)*((1.16x3)/0.2)

F = 782.6 N

4.1.6 Volume of the blade (semi circular):

R=0.035m

r=0.032m



Thickness, t = $2x10^{-3}$

Diameter, d= 0.07m

Height, h = 0.3m

Volume for circular, $V = \pi.h.(R^2 – r^2)$

$= \pi (0.3) (0.035^2 - 0.032^2)$

$= 1.894x10^{-4} m^3$

Volume for semi circular = $1.894x10^{-4} m^3 / 2$

$= 9.472x10^{-5} m^3$

Density, ρ (Al) = m / V

$2700 = m / (9.472x10^{-5} m^3)$

m = 0.256 kg (1 blade) x 8

= 2.046 kg

4.1.7 Volume for Shaft

Diameter, d = 0.2 m

Height, h = 0.6 m

$V = \pi.h.r^2$

$= \pi(0.6)(0.01)^2$

$= 1.885 x10^{-4} m^3$

Density, ρ (Al) = m / V

$2700 = m / 1.885 \times 10^{-4}\ m^3$

m = 0.509 kg

4.1.8 Volume of the Disk

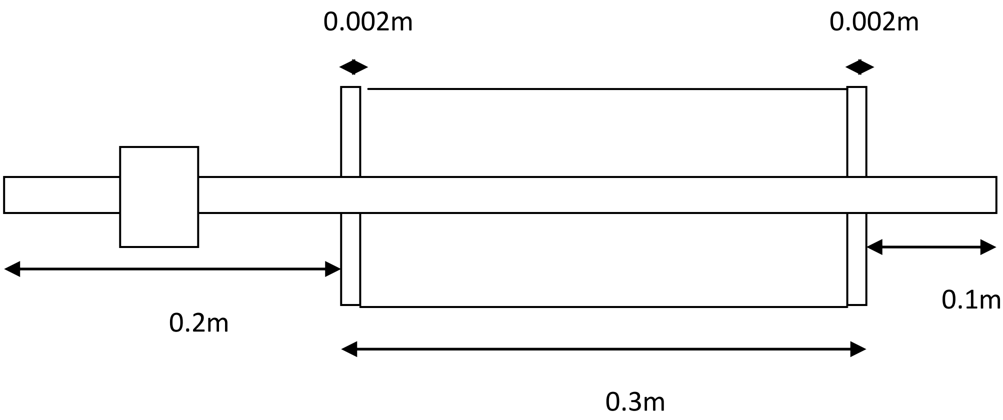
$V = \pi.h.r^2$

$= \pi(2 \times 10^{-3})(0.09)^2$

$= 5.089 \times 10^{-5}\ m^3$

Density, ρ (Al) = m / V

m = 0.137 kg



4.1.9 DC Motor

Magnet that has been used in this project is N48 Neodymium magnet.

N48 = 13800-14200 Gauss

= 13.8-14.2 KGs

10 000 Gauss = 1 Tesla

If 14200 Gauss magnet has been used, it would be 1.42 Tesla.

Magnet Size:

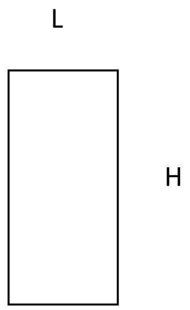
Height= 3cm

Length= 1.3 cm

Width= 0.6 cm

Area = 3.9 cm^2

= 0.00039 m^2



By using Faraday law,

V = -N * change in ((tesla * area meters squared)/ seconds)

To find the Number of Turns, it becomes:

N = -1*(-V/ change in ((tesla x area meters squared)/second))

N=-1*(-V/((T*A)/S)

N = number turns

V = volts

T = strength of the magnet in Tesla

A = area of the magnet in meters squared

S = times the magnet passes the coil per second

By assuming 14 Volt has been used

Total number of coil needed is:

N = -1 (-14 / ((1.42 * 0.00039)/0.2))

= 5056 windings

In this project, 12 magnets has been used, this would give:

1 magnet = 421 windings.

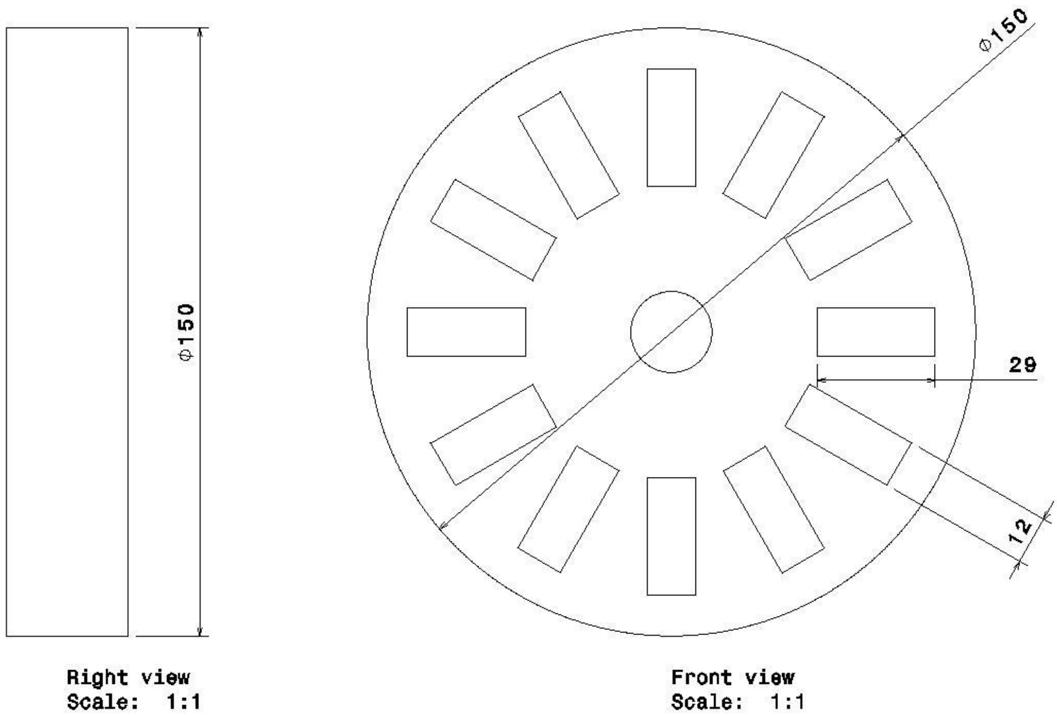


Figure 22: Dimension for Rotor

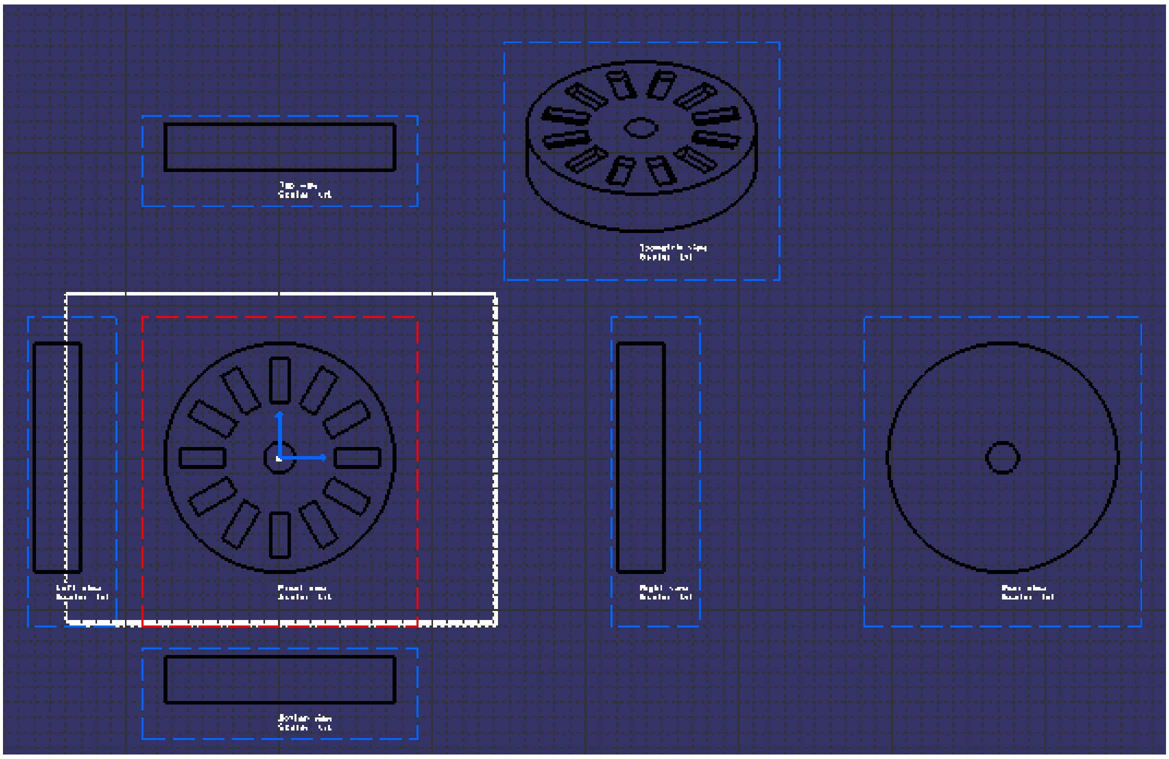


Figure 23: Exploded View for Rotor

Figure 24: Stator

Figure 25: Rotor

4.2 Theoretical Power Output

Theoretical power produced had been calculated by considering the worst case scenario at 50% of turbine efficiency. The equation of the power output comes from $P = \frac{1}{2}\eta\rho A v^3$. The other variables such as water velocity and area of attack can varied to get the maximum possible power produced.

In this calculation, the water speed is taken as low as 0.5 m/s until 3 m/s. The power produced is being compared as the area of water attack also being varied.

a) Power when the area is $0.015m^2$

Length(m)	Width(m)	Area(m^2)	Efficiency,η	Velocity(m/s^2)	Power(W)	P (kw)
0.3	0.02	0.015	0.5	0.5	0.46875	0.00046875
0.3	0.02	0.015	0.5	1	3.75	0.00375
0.3	0.02	0.015	0.5	1.5	12.65625	0.01265625
0.3	0.02	0.015	0.5	2	30	0.03
0.3	0.02	0.015	0.5	2.5	58.59375	0.05859375
0.3	0.02	0.015	0.5	3	101.25	0.10125

Table 4: Power when the area is $0.015m^2$

b) Power when the area is 0.012m²

Length(m)	Width(m)	Area(m²)	Efficiency,η	Velocity(m/s²)	Power(W)	P (kw)
0.3	0.02	0.012	0.5	0.5	0.375	0.000375
0.3	0.02	0.012	0.5	1	3	0.003
0.3	0.02	0.012	0.5	1.5	10.125	0.010125
0.3	0.02	0.012	0.5	2	24	0.024
0.3	0.02	0.012	0.5	2.5	46.875	0.046875
0.3	0.02	0.012	0.5	3	81	0.081

Table 5: Power when the area is 0.012m²

c) Power when the area is 0.009 m²

Length(m)	Width(m)	Area(m²)	Efficiency,η	Velocity(m/s²)	Power(W)	Power(kw)
0.3	0.02	0.009	0.5	0.5	0.28125	0.00028125
0.3	0.02	0.009	0.5	1	2.25	0.00225
0.3	0.02	0.009	0.5	1.5	7.59375	0.00759375
0.3	0.02	0.009	0.5	2	18	0.018
0.3	0.02	0.009	0.5	2.5	35.15625	0.03515625
0.3	0.02	0.009	0.5	3	60.75	0.06075

Table 6: Power when the area is 0.009 m²

d) Power when the area is 0.006 m²

Length(m)	Width(m)	Area(m²)	Efficiency,η	Velocity(m/s²)	Power(W)	Power (kw)
0.3	0.02	0.006	0.5	0.5	0.1875	0.0001875
0.3	0.02	0.006	0.5	1	1.5	0.0015
0.3	0.02	0.006	0.5	1.5	5.0625	0.0050625
0.3	0.02	0.006	0.5	2	12	0.012
0.3	0.02	0.006	0.5	2.5	23.4375	0.0234375
0.3	0.02	0.006	0.5	3	40.5	0.0405

Table 7: Power when the area is 0.006 m²

e) Power when the area is 0.003 m²

Length(m)	width(m)	Area(m²)	efficiency,η	velocity(m/s²)	Power(W)	P(kw)
0.3	0.02	0.003	0.5	0.5	0.09375	0.00009375
0.3	0.02	0.003	0.5	1	0.75	0.00075
0.3	0.02	0.003	0.5	1.5	2.53125	0.00253125
0.3	0.02	0.003	0.5	2	6	0.006
0.3	0.02	0.003	0.5	2.5	11.71875	0.01171875
0.3	0.02	0.003	0.5	3	20.25	0.02025

Table 8: Power when the area is 0.003 m²

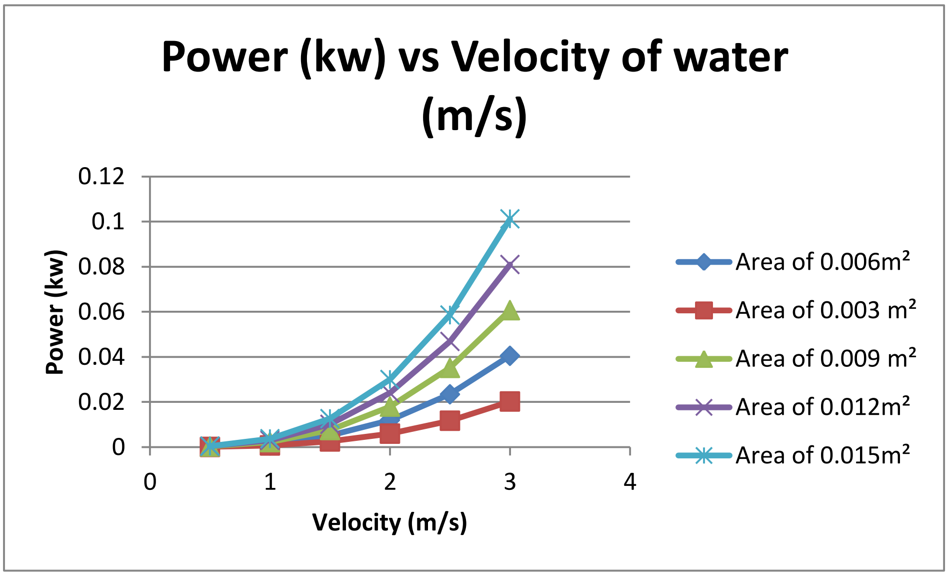


Figure 26: Graph of Power produced (KW) vs Water Speed (m/s)

From the graph above, the power produced by the turbine is proportional to the water speed and the area of water attack. At the 50 % of the turbine the maximum power can be produced is 0.1 kw when the area of water attack is 0.015 m². At this worst case scenario, the power produced is very small to meet the objective of the project. The efficiency of the turbine plays an important role for this project. Having higher efficiency of turbine can produced a better result for power output.

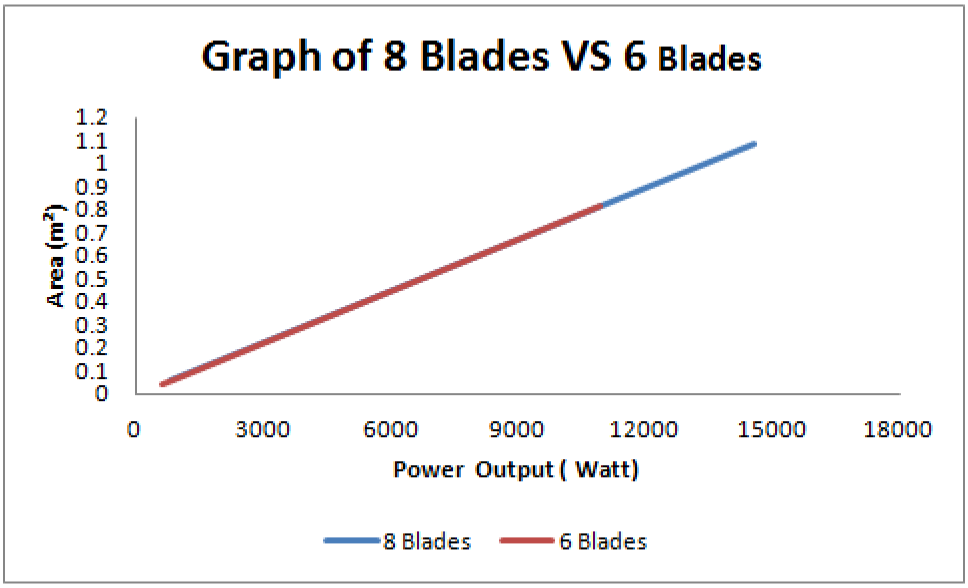


Figure 27: Comparison Between 8 Blades and 6 Blades Used

Experimental Result

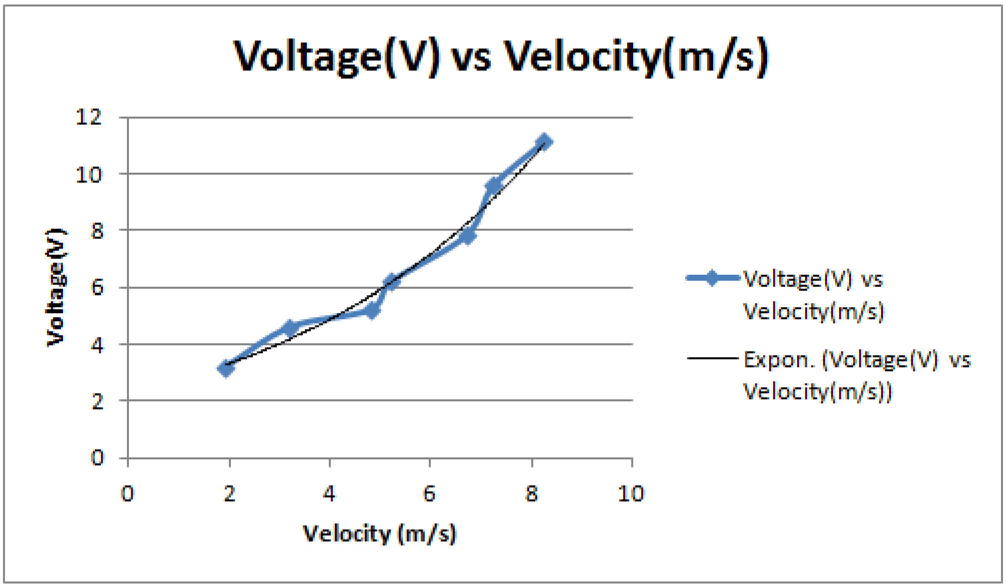


Figure 28: Graph of Experimental Result

Distance (m)	Air velocity (m/s)	Voltage (V)	Power (W)	Current (I)	Angular speed (rad/s)	Torque (Nm)
0.25	8.24	11.14	32.90	2.95	74.91	0.44
0.5	7.24	9.6	22.31	2.32	65.82	0.34
0.75	6.71	7.84	17.76	2.27	61.00	0.29
1	5.22	6.2	8.36	1.35	47.45	0.18
1.25	4.8	5.22	6.50	1.25	43.64	0.15
1.5	3.2	4.6	1.93	0.42	29.09	0.07
1.75	1.93	3.2	0.42	0.13	17.55	0.02

*assume tip speed ratio=1

Table 9: Calculation Data from experimental Result

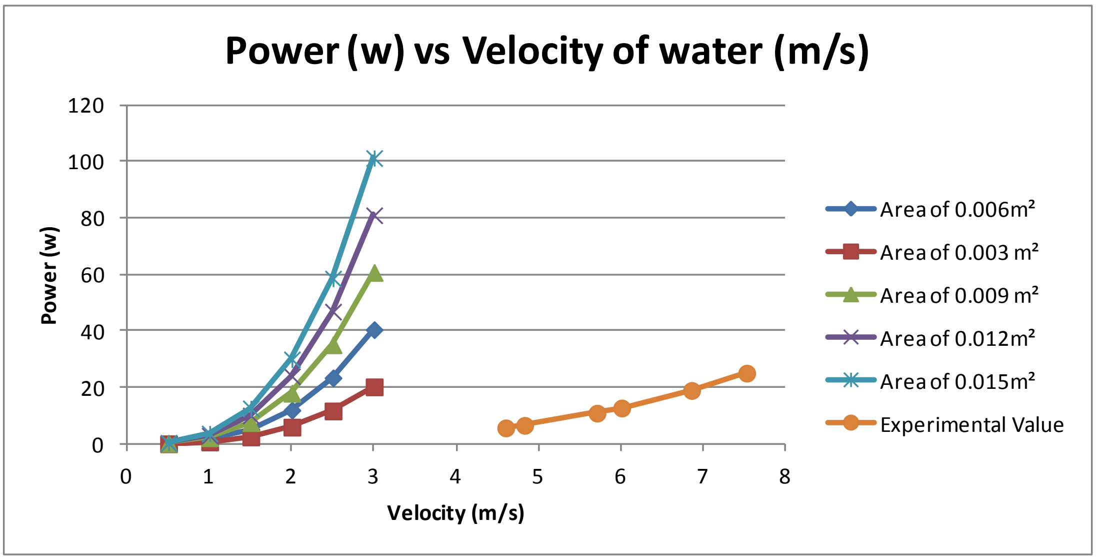


Figure 29: Graph of Experimental Result vs. Theoretical Result

From the experimental value, we can see that power produce is increasing as the velocity of the air increased. 0.42 Watt of power produces when the velocity of air is minimum, which is 1.93 m/s. The maximum power that can be recorded is around 32 Watt when the velocity of air is 8.24 m/s.

However, comparing the theoretical value and the experimental value, we can see that the experimental value produces very low of power output even though it experiences high speed of the wind which is around 4 m/s to 8 m/s.

There are some reason why the power output for the experimental value is very low. The experiment should be conducted at the site location, which is at the river. Due to circumstances and time constrain, the test was conducted by using a blower. From this situation, the water turbine was tested by using air instead of water. This is done just to get know whether the designed turbine is function well or the other way. The difference of the velocity profile and point of contact of the air towards the blades affect the power output that we get.

Another factor that might affect the power output is the blade design. Theoretically, the design of the blade is to be semi circular. But due to fabrication problem, the design has been change to flat blades. As the less effective of flat blade compared to the semi circular blades, the power output produce is lesser from what is expected.

During the experimental process, the turbine experiences the difficulty to turn even though the velocity of the wind is high enough for the blade to turn. This is due to the stalling effect of the blades.

Stalling effect is mainly depends of angle of attack and not the wind speed. Turbulence will happen as the angle of attack is increased. Stall can be initiated when the turbine blade is not smooth. In this case, a dent in the blade can produce a turbulance at the backward of the blade.

Another factor that affects the low power output is the design of the housing. Previously, the housing design is freely open. To increase the possible power to the maximum, the design of the housing should mainly allow the water to enter on one side only and will turn the blade without any turbulence effect and stalling effect.

Generator that has been used in this testing also gives effects to the power output produce. Small generator used will also give a small output. There are several factors that affect the capacity of the generator. One of them is the number of coil. Higher number of coil and thickness will give a higher output. Types of magnet and the strength of magnet will give a strong effect of the magnetic flux produced.

5.0 Conclusion and Recommendations

The aim of this project is to design and fabricate a vertical crossflow turbine. This is achieve by successfully fabricate a turbine as been designed. Testing process had been done and small electrical power is produced. From the result, output from the theoretical and experimental has been compared. As a conclusion, the theoretical power produced from the turbine is proportional to the velocity of water and the area of water attack. The power that can be generated can be improvised by increasing the efficiency of the turbine and increasing the other variables. The power produced can give sufficient electricity in rural area although the range is small compared to other types of turbine. The idea of vertical crossflow run river micro turbine can protect or at least save the environment from being destroyed.

For further works on zero head hydro turbine, several recommendations and improvement that can be made as the next step in the project:

a) Fabrication process must be done neatly without any mistakes to reduce any potential error while testing.

b) While folding the aluminium for blade fabrication, make sure it bends symmetry to each other.

c) The windings that have been used for stator must be done perfectly to minimize any air gap. Having air gap in the windings will result in decreasing the power produced in generator

d) Design a housing that will allow the water to enter one side only and thus, reduce the turbulence effects and the stalling effects of the blades.

e) Bigger generator or size of magnets and higher strength of magnets can be used to get extra power produced.

f) In this case, several turbines can combined in series to get the higher power output and thus, meet the requirement.

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FYP 1

No	Details/ Week	1	2	3	4	5	6	7	Mid Semester Break	8	9	10	11	12	13	14
1	Project Topic Selection															
2	Preliminary Research Work															
3	Undertanding Concept, Formulas, Laws & Calculations															
4	Submission of Extended Proposal Defence															
5	Proposal Defence Presentation															
6	Understanding & Formulating Calculations															
7	Designing Turbine & Project Work Continues															
8	Submission of Intrim Draft Report															
9	Submission of Intrim Report															

Indicator:

Process

Suggested milestone

FYP 2

No	Details/ Week	1	2	3	4	5	6	7	Mid Semester Break	8	9	10	11	12	13	14	15
1	Project Work continues																
2	Designing Turbine & Project Work Continues																
3	Mock-Up Test																
4	Fabrication																
5	Testing Process																
6	Submission of Progress Report																
7	Designing Turbine & Project Work Continues																
8	Pre-EDX (SEDEX)																
9	Submission of Draf Report																
10	Submission of Dissertation																
11	Submission of Technical Paper																
12	Oral Presentation																
13	Submission of Project Dissertation																

Indicator:	
	Process
	Suggested milestone