" I hereby declare that I have read this fully report entitled " *Design and Development of a Low Cost and Portable Pico Hydro Turbine*" and found that it has comply the partial for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

Signature : ………………………………

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Date : 1 June 2015

DESIGN AND DEVELOPMENT OF LOW COST AND PORTABLE PICO HYDRO TURBINE

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A report submitted in partial fulfillment of the requirements for the degree of Electrical Engineering (Industrial Power)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

I declare that this report entitled "*Design and Development of a Low Cost and Portable Pico Hydro Turbine*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	……………………………….
Name	:	Syahrunizzam Bin Hassin
Date	:	1 June 2015

To my beloved mother and father

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Firstly, my biggest thanks to Allah S.W.T who gave me the opportunity in doing this project and always giving me hope and ways in completing the tasks.

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ABSTRACT

The goal of this research is to design, develop and analysis of a low cost and portable Pico hydro turbine. Hydro turbine has become an interest as it widely used around the world, especially in the rural area in Malaysia. The main reason why the hydro turbine is so widely used is due to their renewable source of producing electrical energy which is water. The focus on this project is to develop a portable Pico hydro that can be installed anywhere especially in the house. The project will involve two main phases: the designing of the turbine and the analysis of the turbine using different shape of pipe on the incoming water source. The designed turbine should be capable to meet performance specification for hydropower generation, such as an adequate minimum rate of flow and the type of turbine design used. The power supplied by falling water is the rate at which its deliver energy and this depends on the mass flow rate of the water, which can be manipulated by designing a different shape of pipe at the input water source. To meet the requirement, some issue needs to be considered in designing such as selection of the shape of the incoming pipe water source, design of turbine and size, design of the blade, and the type of the generator.

ABSTRAK

Matlamat kajian ini adalah untuk mereka bentuk, membangunkan, analisis dan menghasilkan turbin Pico hidro mudah alih dengan kos yang rendah. Turbin hidro telah menjadi suatu kepentingan kerana ia digunakan secara meluas di seluruh dunia, terutama di kawasan luar bandar di Malaysia. Antara sebab utama mengapa turbin hidro yang digunakan begitu meluas adalah disebabkan oleh sumber yang boleh diperbaharui untuk menghasilkan tenaga elektrik iaitu air. Tumpuan kepada projek ini adalah untuk membangunkan turbin Pico hidro mudah alih yang boleh dipasang di mana-mana terutamanya di dalam rumah. Projek ini akan melibatkan dua fasa utama iaitu: mereka bentuk turbin dan analisis turbin menggunakan bentuk paip yang berbeza di sumber air yang masuk. Turbin direka harus mampu untuk memenuhi spesifikasi prestasi bagi penjanaan kuasa hidro seperti kadar minimum yang mencukupi aliran dan jenis reka bentuk turbin yang digunakan. Kuasa yang dibekalkan oleh air jatuh adalah kadar di mana pnghasilan tenaga ini bergantung kepada kadar aliran jisim air, yang boleh dimanipulasi oleh reka bentuk paip yang berbeza di sumber air masuk. Bagi memenuhi keperluan ini, beberapa isu perlu dipertimbangkan dalam mereka bentuk seperti pemilihan bentuk sumber air paip masuk, reka bentuk turbin dan saiz, reka bentuk mata turbin itu, dan jenis generator.

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V	-	Voltage
DC	-	Direct Current
AC	-	Alternating Current
m	-	Metre
g	-	Gravity = 9.81 m/s
W	-	Watt
M	-	Mega
K	-	Kilo
psi	-	Pound per square inch
RPM	-	Rotation per minute
Q	-	Flow rate
P	-	Pressure
H	-	Water head

CHAPTER 1

INTRODUCTION

Research on alternative ways to generate electricity is going aggressively because the dependence on non-renewable energy sources is diminishing. Hydro generation is one of the energy sources that have yet to be fully explored.

1.1 Project Background

This project is about the development of low cost and portable Pico hydro turbine. A hydro turbine is a renewable energy whereby it generates energy by converting kinetic energy from water movement into electricity. The Pico hydro turbine is another option for gathering electric power from moving water sources by using a small water turbine fed from a household water pipe. In this project, the usage of water turbine that suitable and can adapt to the small pressure of household water pipe will be focusing on.

Basically, this project will do an analysis of the best shape of the household incoming water pipe that can effect on the speed of the water turbine. In order to do an analysis, the selection of the water turbine shape and size will be greatly facilitated while keeping the desired hardware aspect in mind. As for the desired hardware aspect, the selection of the blade design and the generator type to be used will be selected to comply with the requirement of the desired hardware. In this analysis, some finding or conclusion should be obtained to know the performance of the portable Pico hydro turbine in service.

1.2 Project Motivation

It is motivated to study and do this project because of the high demand from industry that need to produce a renewable energy in a minimum cost so that it can be installed widely especially at the rural area. Nowadays, the biggest problem of transferring electricity to the rural area is the cost itself. As the cost come with the problem, most of the electricity generation comes with a big size that will install permanently in the specific area. This unresolved problem has led to the lack of power generation in the rural area that can only be solved by designing a low cost and portable renewable energy turbine.

1.3 Problem Statement

The development of a low cost and portable Pico hydro turbine is not a simple task. Generally, knowledge of electrics, magnetics, electronics and mechanics is required. Thus, the electrical and mechanical relationships are important and should be taken into account in designing the portable Pico hydro turbine. Turbine selection and design are the most crucial parameter to be determined in designing the low cost and portable Pico hydro turbine, which is either to use the reaction turbine or impulse turbine. Selection of the generator will potentially affect the outcome of the project, either it can produce power at the determine rate.

For these reasons, it is important to design a good generator and turbine at smaller size with a reliable, affordable, economically viable and socially acceptable to ensure it will produce a smooth mechanical rotation and output.

1.4 Objectives

The objective of this project is to:

1. To understand the concept and the design of hydro turbine
2. To design and develop a low cost and portable Pico hydro turbine
3. To analyse the best shape to be used in the design of incoming water source pipe

1.5 Scope of Work

The scope of work is limited to:

1. The 12V DC motor will be used as the generator.
2. The shape of incoming water source pipe used is original shape, baffle shape and nozzle shape.
3. Minimizing the cost of the material that use of the turbine and the hardware.
4. Develop the hardware so that it can fit in the consumer's pipe.
5. Testing in the low-head hydro turbine (4m) parameter.

1.6 Contribution of Work

Hydropower is an extremely proficient wellspring of renewable energy. Due to the thickness of water and the power of gravity (among other factor) the hydropower innovative favourable circumstances of today are that these frameworks can clandestine up to 90% of the vitality of water into electric vitality, which is an astounding number [1][2].

Since hydro force is powered by water, it has the benefit of being just utilized when required, in light of the fact that it is anything but difficult to control the capacity and allowable flow of water into a hydropower framework. Hydropower has preference over wind power in light of the fact that water is thicker than air, so gathering the mechanical vitality of wind obliges a more prominent power of wind to turn the turbine than it would for water in a hydropower framework[2].

CHAPTER 2

LITERATURE REVIEW

Theories related in development of low cost and portable Pico hydro turbine will discuss in this chapter.

2.1 Theory and Basic Principles

Most of the energy in the world is wasted out without have been used in a proper way to gain an energy. The renewable source of energy such as water is the fundamental reason why hydropower is possible. The water cycle, which is starting from the sun that reaches the earth's surface causes water to operate and hence a proportion of this energy causes the vapour to rise against the earth's gravitational pull. This vapour then condenses into rain and snow, which again falls back to the earth's surface [3].

When rain and snow fall onto any ground above sea level, some of the sun's energy is conserved in the form of potential energy. This energy is then dissipated in currents as water runs down in streams. By catching this water in controlled form of pipe, we can exploit the kinetic energy that becomes available with the movement of water, under pressure onto a turbine blade. The water then strikes the turbine blade to create mechanical energy [2] [3]. This mechanical energy is then transmitted to an electrical generator through a rotating shaft [2].

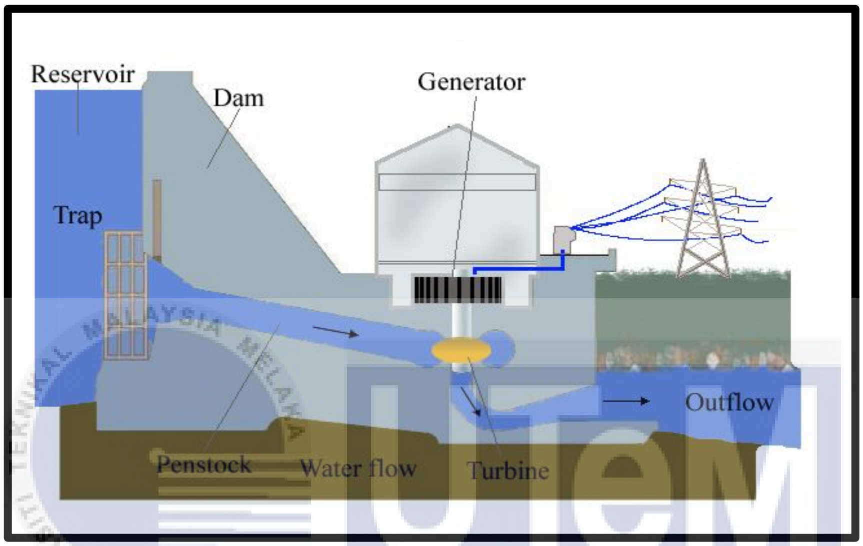


Figure 2.1: How hydro Turbine works [2]

The earliest reference to the use of the energy of falling water is found in the work of the Greek poet Antipater in the 4th century BC, however the Romans were the first to be documented as using waterwheels and they spread their use across Europe, in the form of mills for grinding cereals. By 1800, tens of thousands of such mills had been built worldwide [4].

By the end of the 19th century water wheel technology had advanced considerably and the first water turbines, as they were now called, were used to produce electricity. The earliest recorded hydroelectric plant began generating in 1882, in the USA, on the Fox River near Appleton, Wisconsin. Since that time the contribution of hydroelectric power to world use of electricity has risen steadily and today hydroelectricity is the principal source of electric power in some 30 countries and provides about 20% of the world's annual electrical output [4].

The very first hydro-plants were relatively small schemes, however, subsequent developments were around very large schemes and today most of the hydroelectric power is produced from very large hydro-plant associated with dams, which were major capital projects. Large dams are still being built today, however the majority are located in the developing world, where between 1980 and 1986 the absolute increase in hydro generation was almost twice that of the industrialized world [4].

The hydroelectric plants work by converting the kinetic energy from water falling into electric energy. This is achieved from water powering a turbine, and using the rotation movement to transfer energy through a shaft to an electric generator.

Figure 2.2: Early hydro turbine design [4]

Hydroelectric power, using the potential energy of rivers, now supplies 17.5% of the world's electricity (99% in Norway, 57% in Canada, 55% in Switzerland, 40% in Sweden, 7% in the USA) [4]. Apart from a few countries with an abundance of it, hydro capacity is normally applied to peak-load demand, because it is so readily stopped and started. It is not a major option for the future in the developed countries because most major sites in these countries having potential for harnessing gravity in this way are either being exploited already or are unavailable for other reasons such as environmental considerations. Growth for 2030 is expected, mostly in China and Latin America.

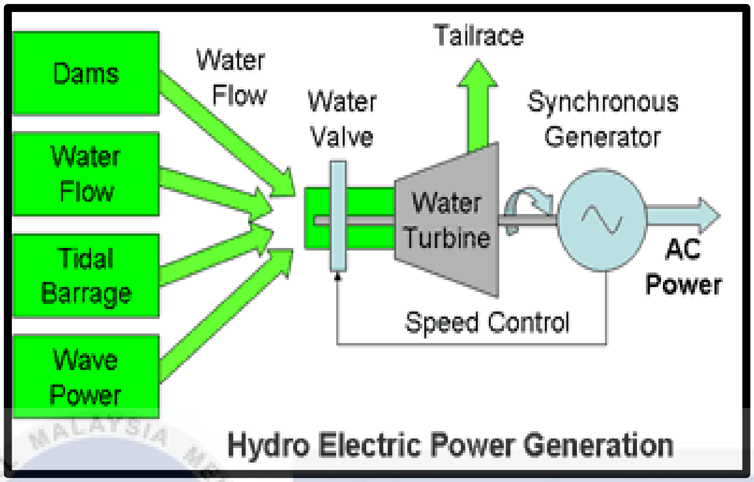


Figure 2.3: Sources for hydroelectric power [5]

Hydro energy is available in many forms, potential energy from high heads of water retained in dams, kinetic energy from current flow in rivers and tidal barrages, and kinetic energy also from the movement of waves on relatively static water masses. Many ingenious ways have been developed for harnessing this energy, but most involve directing the water flow through a turbine to generate electricity.

Hydro power is a very clean source of energy and only uses the water, the water after generating electrical power, is available for other purposes. Due to this reason, hydropower plants become more important. There are few types of hydropower plant which depends on the size which is the large, small, mini, micro, and Pico [5].

1. Large Hydro (10 MW or more of generating capacity)
2. Small Hydro (1 to 10 MW of generating capacity)
3. Mini Hydro (100 KW to 1 MW of generating capacity)
4. Micro Hydro (5 KW to 100 KW of generating capacity)
5. Pico Hydro (less than 5 KW of generating capacity)

2.2 Water Turbines

A water turbine is a rotary engine that takes energy from moving water. Water turbines were developed in the nineteenth century and were widely used for industrial power prior to electrical grids. Now they are mostly used for electric power generation. They harness a clean and renewable energy source.

Flowing water is directed onto the blades of a turbine runner, creating a force on the blades. Since the runner is spinning, the force acts through a distance (force acting through a distance is the definition of work). In this way, energy is transferred from the water flow to the turbine. Water turbines are divided into two groups; reaction turbines and impulse turbines. The precise shape of water turbine blades is a function of the supply pressure of water, and the type of impeller selected [6] [7].

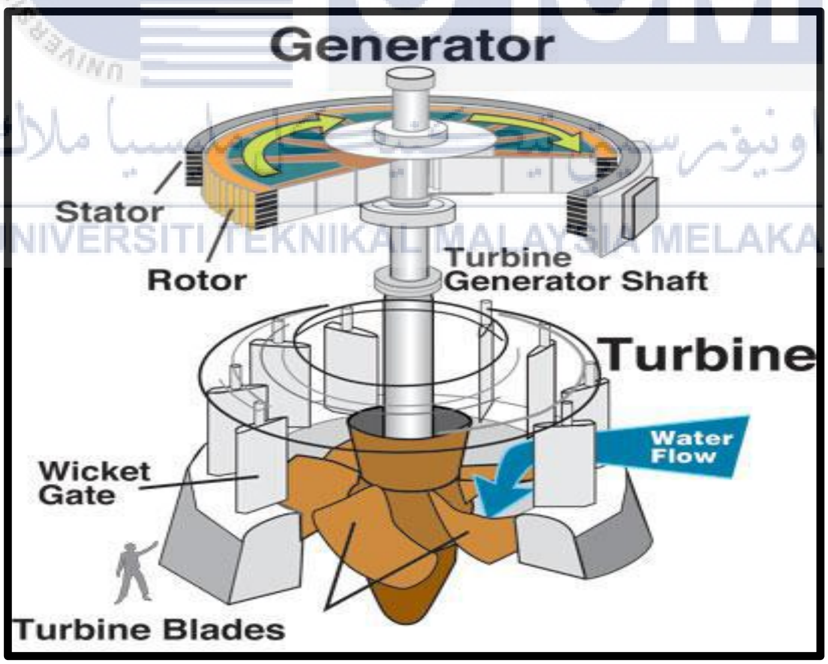


Figure 2.4: Hydraulic turbine and electrical generator, cutaway view [7]

2.2.1 Classification of Water Turbine

Water turbine fall into two categories which is:

1. Impulse Turbine
2. Reaction Turbine

2.2.2 Impulse Turbine

An impulse turbine operates on the same principle as a toy pinwheel. Water strikes the turbine runner, and pushes it in a circle. The water is delivered to the runner through a pipeline, and out a small nozzle which maximizes the force available to operate the turbine.

These types of water turbines work best on sites where the water source has high head (20 feet or more). The head is the vertical distance between where the water enters the turbine system (in this case, into a pipeline) and where it reaches the turbine runner. Small impulse water turbines require minimal water flow volume, so they are ideal for sites where a relatively small amount of water runs down a fairly steep hill, as in a hillside stream or small waterfall. The most well-known type of impulse turbine is the Pelton wheel style as used in Harris Pelton turbines. But in higher flow sites, a Turgo style runner such as the one used in the Stream Engine has a higher output potential [7].

Impulse turbines change the velocity of a water jet. The jet impinges on the turbine curved blades which change the direction of the flow. The resulting change in momentum (impulse) causes a force on the turbine blades. Since the turbine is spinning, the force acts through a distance (work) and the diverted water flow is left with diminished energy. Prior to hitting the turbine blades, the water pressure (potential energy) is converted to kinetic energy by a nozzle and focused on the turbine. No pressure change occurs at the turbine blades, and the turbine doesn't require housing for operation. Newton's second law describes the transfer of energy for impulse turbines.Impulse turbines are most often used in very high head applications.

- Pelton Turbine [6] [7]

The Pelton turbine is an example of a pure impulse turbine and is named after its inventor, L.A. Pelton (1829-1908) who, in 1880 is patented and improved this form of impulse wheel.This machine is generally used in applications where there is a relatively small rate of flow at a large head, typically above 250m. It is an example of a pure impulse machine in which the pressure of the whole head is converted to velocity in one or more nozzles in parallel

. The jet from the nozzles smoothly traverses the buckets mounted on the runner and the change in momentum results in a rotational force. Figure 2.5 shows the arrangement of Pelton turbine.

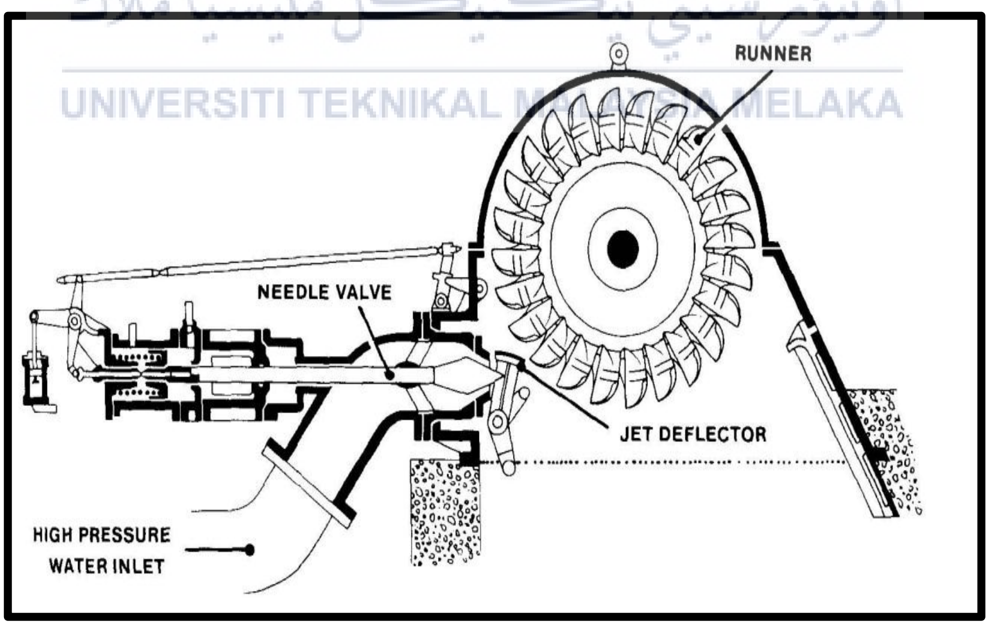


Figure 2.5: Pelton Wheel Turbine [7]

- Turgo Wheel Turbine [6] [7]

The impulse wheel is usually employed in a medium head turbine because the water jet is directed obliquely to one side of the runner and discharged from the other side before it falls into the tail-race. The Figure 2.6 shows a Turgo wheel whilst Figure 2.7 shows the path of the water through a wheel of this type.

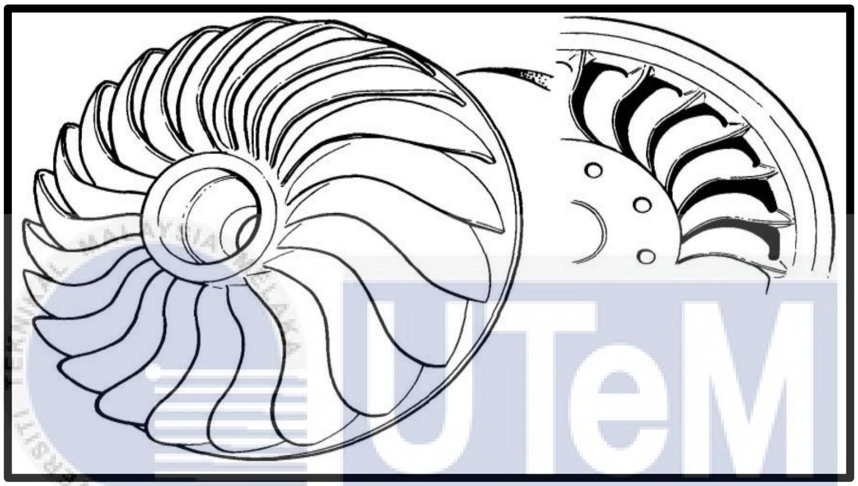


Figure 2.6: Turgo Wheel Turbine [6]

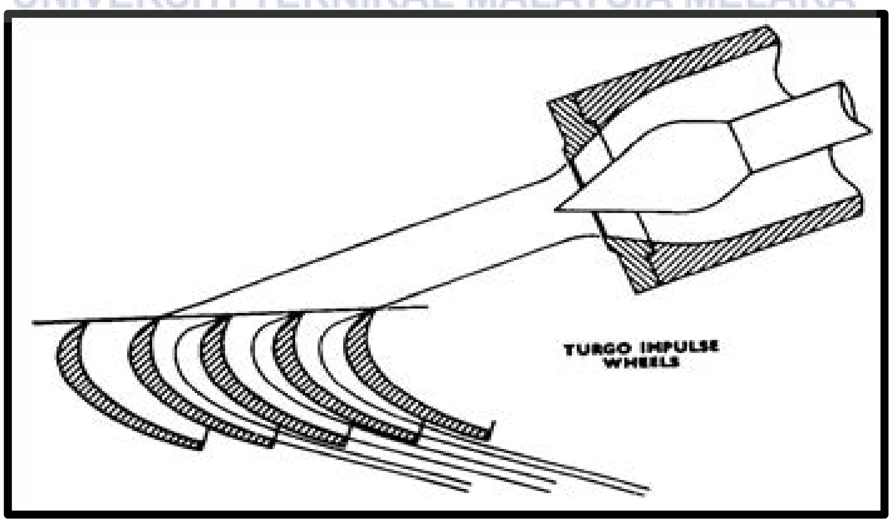


Figure 2.7: Path of water jet through Turgo Wheel Turbine [7]

2.2.3 Reaction Turbine

Reaction turbines require a much larger amount of water flow than impulse styles, but can operate with as little as two feet of head, making them ideal for sites where there may be relatively flat land, but a large water flow.

With reaction turbines, the water is routed either through a pipeline into an enclosed housing. The turbine runner is immersed in the water, which exits the housing through the turbine, turning the alternator as it 'drops' through the runner blades. No matter which runner style a reaction turbine use, a specially designed outlet tube increases the turbine power output by creating suction as the water exits the system [8].

Reaction turbines act on by water, which changes pressure as it moves through the turbine and gives up its energy. They must be encased to contain the water pressure (or suction), or they must be fully submerged in the water flow. Newton's third law describes the transfer of energy for reaction turbines. Most water turbines in use are reaction turbines. They are used in low and medium head applications.

- Francis Turbine [7] [8]

This turbine is named after J. B. Francis, an American engineer, who set about improving the reaction type of turbines. The original Francis turbine has been modified from time to time to improve its efficiency and today an efficiency of more than 93% has been reached.

The turbine is versatile and can work over a head range of 25m to 550m. Figure 2.8 shows the arrangement of a Francis Turbine.

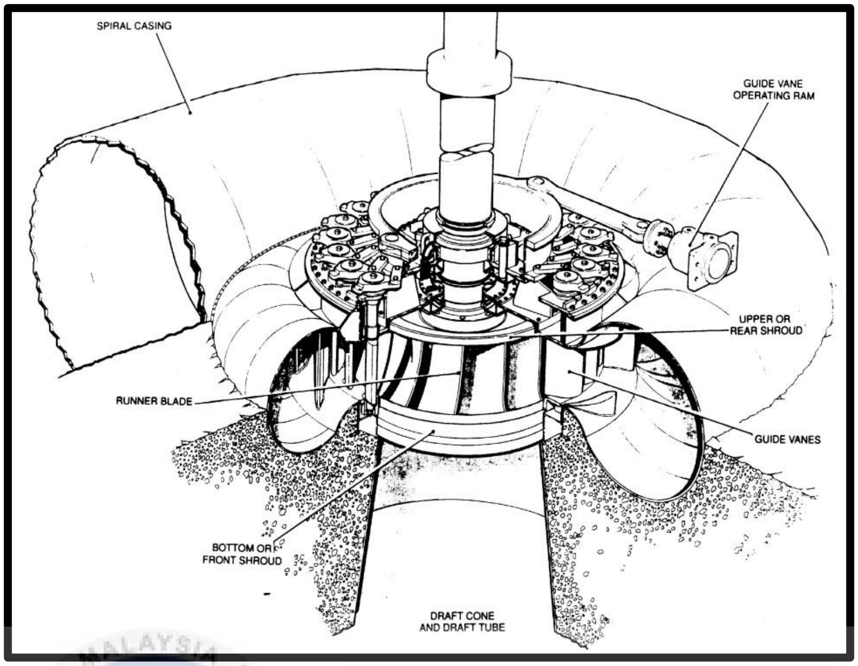


Figure 2.8: Cutaway View shows Arrangement of a Francis Turbine [8]

- Kaplan Turbine [7] [8]

This is a reaction turbine of the axial flow type and is named after Professor Victor Kaplan (1876-1924). The turbine works in a head range of 5 – 60m. Figure 2.9 shows the arrangement.

The essential feature of the Kaplan turbine is that the water flow through the runner is in an axial direction. The inlet spiral casing and the guide vanes are similar in layout and operation of the Francis turbine.

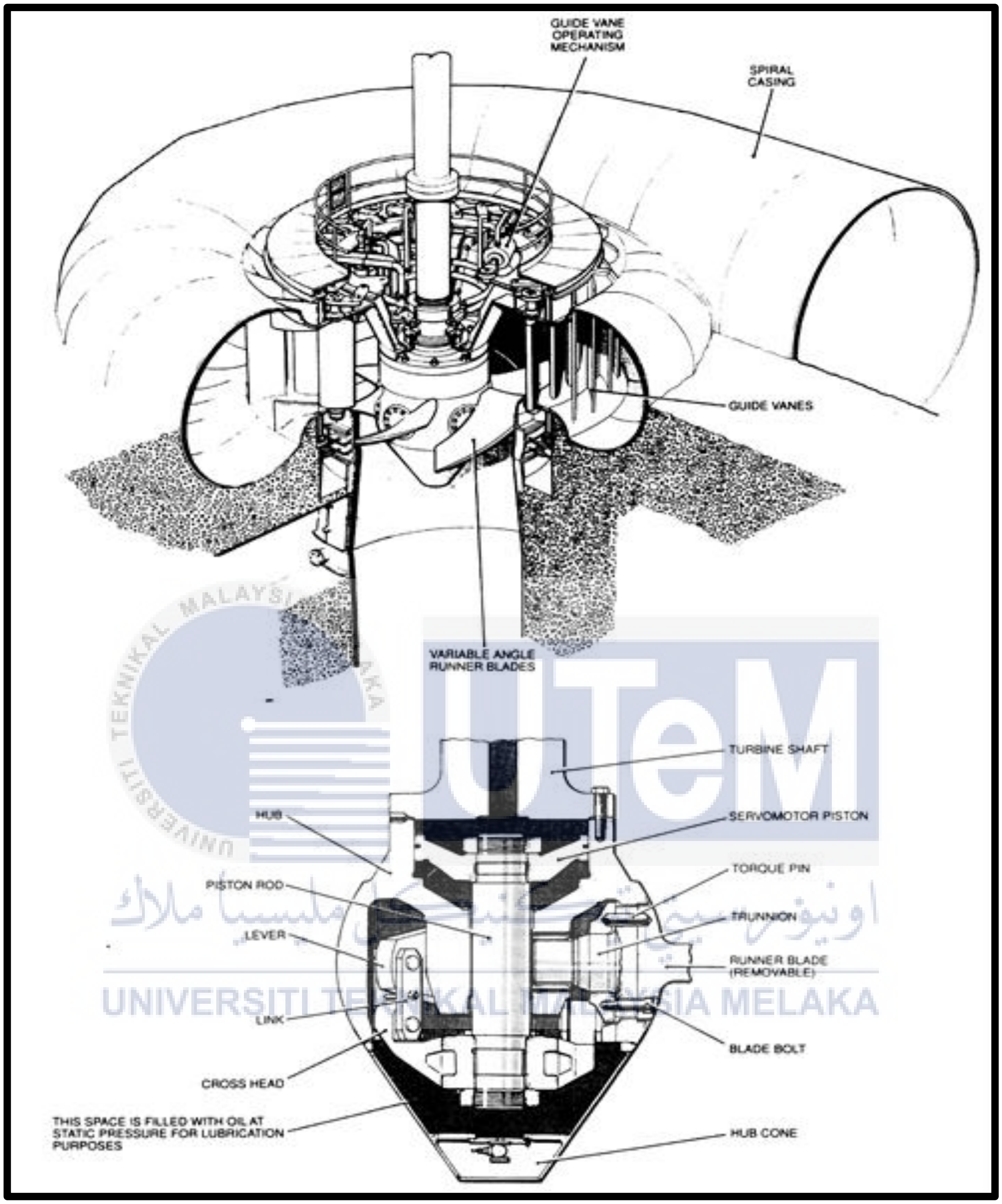


Figure 2.9: Arrangement of Kaplan Turbine [7]

2.3 Generators

A device that converts mechanical energy to electrical energy is known as a generator. A generator is quite similar to that of a water pump. A water pump creates a flow of water, but it does not create water. A generator also creates a flow of charges through its wires but does not create electricity [9]. Sample generators are shown in Figure 2.10. In most cases the source of mechanical energy required for the functioning of a generator comes from:

1. Water falling from a height through a turbine
2. A wind turbine
3. An internal combustion engine
4. Compressed air

Generators are divided into two major categories depending upon the source of current, i.e. Alternating current (AC) and Direct current (DC). Though the basic working principles of both these generators are similar, they differ in construction. These machines are also classified on the basis of the source of the mechanical energy by which they are powered, like water or steam power [9] [10].

If a coil of wire, kept in a magnetic field and connected to a galvanometer, is rotated then current will be induced within the coil [9] [10]. When the current gets induced the galvanometer shows deflection. The factors on which the magnitude of the induced current depends are:

1. Strength of the magnetic field.
2. Length of the coil.
3. The velocity with which the coil rotates within the field.

The main idea behind the rotation of the coil is to make it in motion with respect to the magnetic field. Although in most cases, DC generators have stationary magnetic fields and a rotating coil and vice-versa for AC generators.

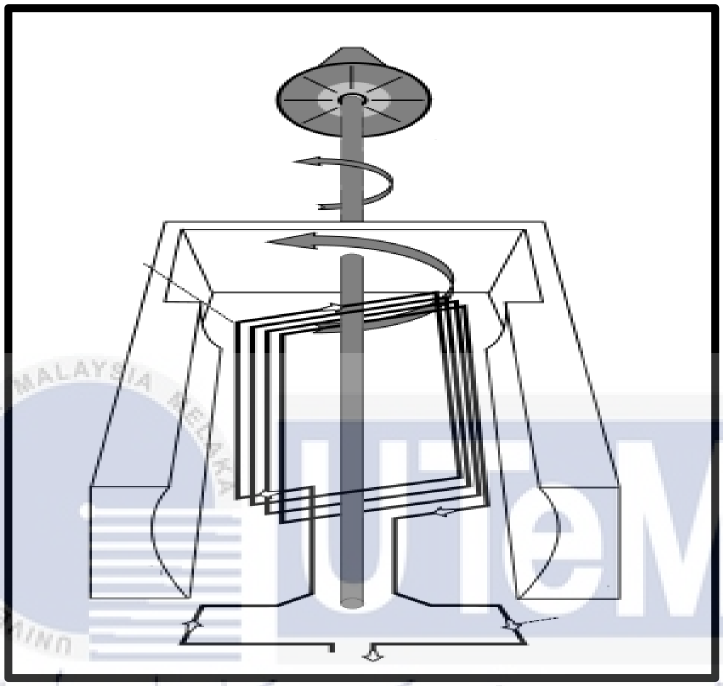


Figure 2.10: Working systems of Generator [9]

2.4 Summary of Literature Review

In this chapter, all the related information for the project completion is stated. The design of turbine and blade of the turbine is discussed and as the main motivation for this project, an explanation of how it works is explained further. In addition, the types of the generator that will be used in the project are discussed. Principles of hydro turbine are explained thoroughly throughout the chapter for implementation into a small scale and portable Pico hydro turbine.

CHAPTER 3

METHODOLOGY

Methodology is about approach of project research and the way the project is conducted. This chapter is extremely important because in the basis of this method, the project can be understood. Other than that, it is on arrangement approach in order on the working procedure to develop the project. Suitable methodology selection facilities implementation and performance can ensure work quality. In this chapter, it is necessary to have an efficient plan to guide into the target which is to achieve the objective.

3.1 Research Flow Chart

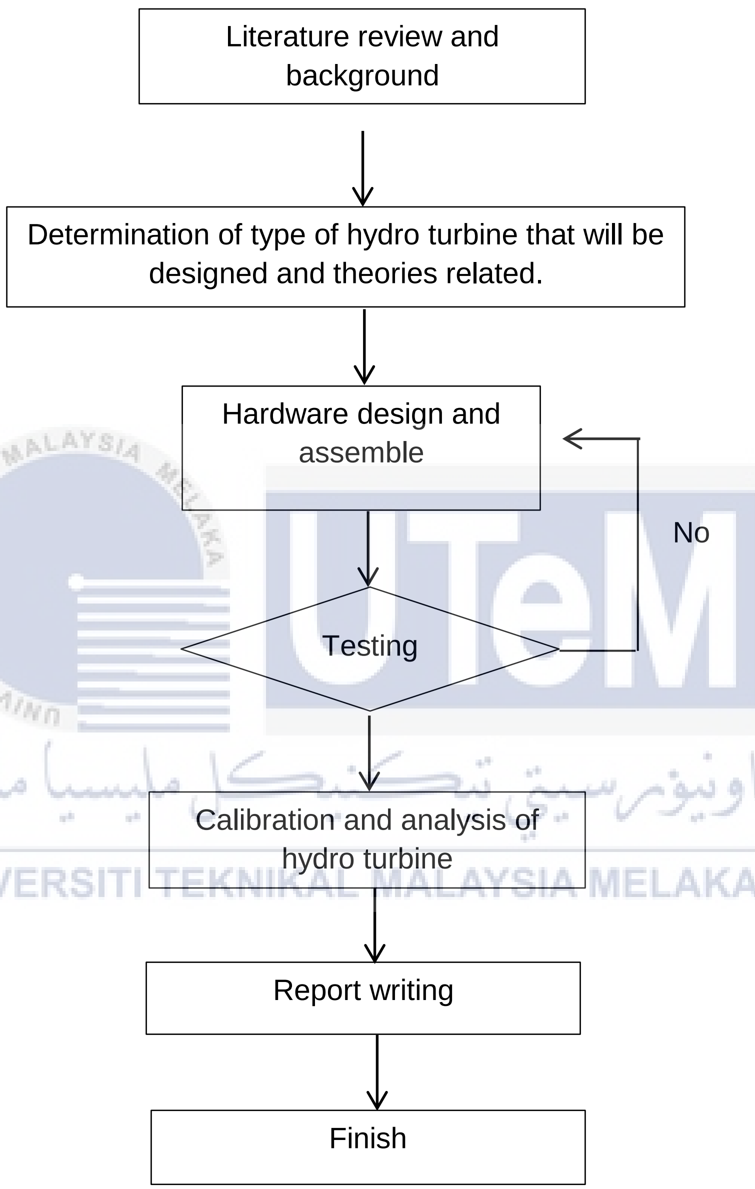


Figure 3.1: Flow chart of the methodology

3.2 Discussion on Selected Technique

This section will elaborate the techniques used in the flow chart shown in Figure 3.1.

3.2.1 Literature Review and Background

This section will elaborate about a study of the previous project, journal and books that related to this project, which is the basic operation and theory of hydro turbine, concept of electrical and mechanical. This step has been further discussed in the previous chapter.

3.2.2 Determination of type of hydro turbine that will be designed and theories related.

In this section, the selection of turbine use in the project is being discussed to select the best type of hydro turbine blade and the generator. With the choice of power types selected, it is important to determine exactly what type of hydraulic generator to employ. The factors that go into selecting an appropriate type of hydro generator are similar to factors that went into selected an appropriate energy source, cost of materials and suitability based on the environment.

The types of hydro turbine, which were considered is a Kaplan turbine, a Francis turbine, and a Pelton turbine. They all have very different designs and as such, the cost of materials varies quite significantly. Furthermore, each of these turbine types is optimal for certain ranges of head. Between these two factors, it is relatively simple to select an appropriate type. A Francis turbine has the basic design and requires a runner as shown in Figure 3.2 below.

Figure 3.2: Francis turbine and a runner [4]

This runner is the portion of the Francis turbine, which actually spins from the flow of the water. The rotation of the runner is then connected to an alternator which converts the mechanical energy into electricity. Unfortunately the runner needs to be a specific shape and there are not many practical devices aside from a Francis turbine which require anything shaped quite like this. As such, these runners are both difficult to build out of scrap parts from other common items and expensive to buy new. In contrast, another option is a Kaplan turbine, which is a variation on a Francis turbine. The basic design of a Kaplan turbine can be seen in Figure 3.3 below.

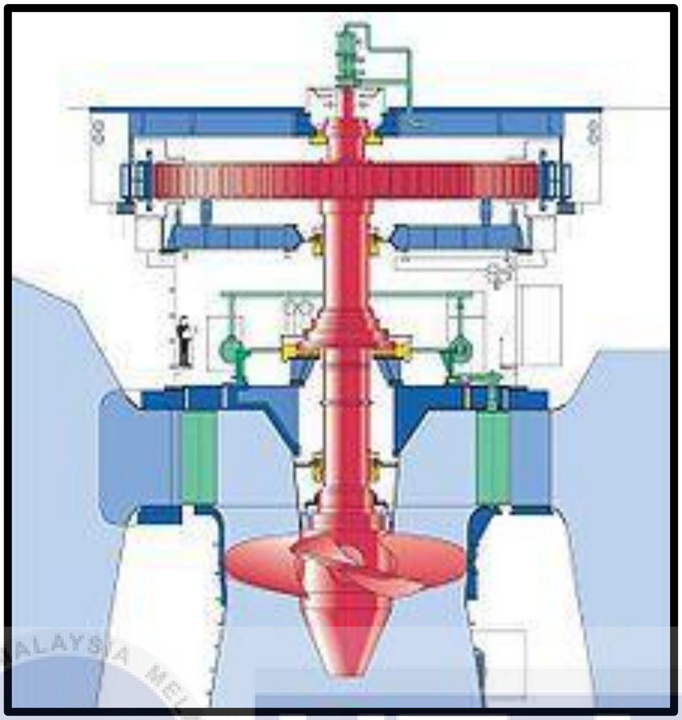


Figure 3.3: Basic design of a Kaplan Turbine [4].

In many ways the Kaplan turbine is similar to the Francis turbine. However, the runner of a Kaplan turbine represents a key difference. It is simply designed to spin as the water moves past it. Unlike the runner on a Francis turbine, this is actually a common shape and can be found in numerous common products. This is obviously beneficial as it drives down the cost of acquiring the part.

The final option considered was a Pelton turbine. The benefits of a Pelton turbine from a cost perspective are quite obvious. It is a simple design as can be seen in Figure 3.4 below.

Figure 3.4: Pelton turbine with its shaft

Perhaps the biggest advantage of a Pelton turbine is that its parts are so simple to design that no mechanical parts would need to be brought to the region, just the alternator. The mechanical components could easily be constructed on site from inexpensive materials. This obviously offers a potentially enormous advantage over any other design.

There is a second design consideration to keep in mind, however, how appropriate each design is for the environment will be emphasized. Consider a house in a common area in Malaysia. The power supply is big enough to accommodate the power demand to the house. As the power supply comes, the water supply for household is a waste energy which can be converted into a green renewable energy. Furthermore, the value of the water pressure of the household is strong enough to move the hydro turbine if it is installed in the household water pipe, as can be seen in Figure 3.5 below.

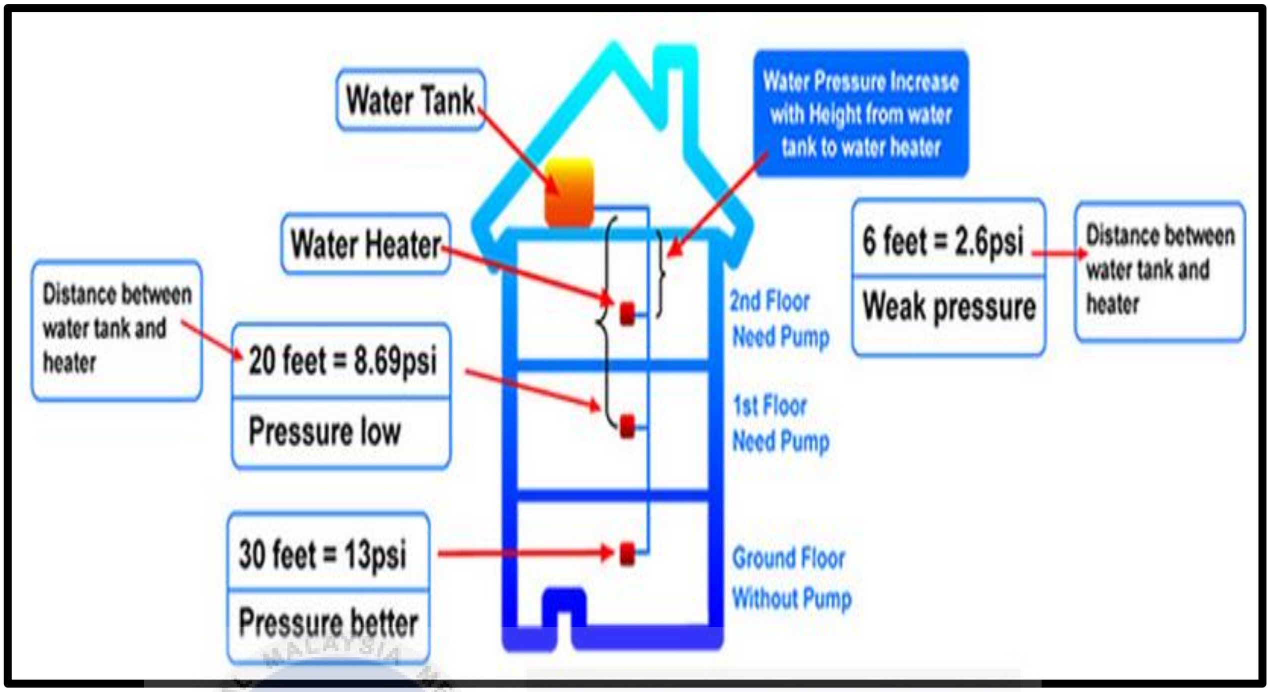


Figure 3.5: 3 storey's Household water pressure [5]

As can be seen in the Figure 3.5 above, the water can flow quite quickly from the water tank and it will easily exceed the 4m maximum head. A Francis Turbine is designed to operate between 10m and 350m. The low end of this scale may be achievable in some rivers, but by in large, the head in a household pipe will be insufficient to really take advantage of the Francis turbine design. Thus, the Francis turbine is undesirable.

This leaves the Kaplan turbine. It has a head range of 2m to 40m, which should be roughly a good fit for the types of household that install a tank at the range between 2m to 40m. When combined with the simple necessary parts, the Kaplan turbine stands as a strong competitor to be selected as the best design, but the cost of the Kaplan turbine is a big disadvantage for the project.

With the above situation in mind, it is possible to compare the various turbines to see which is the most appropriate for the situation. A Pelton turbine, while most likely the cheapest solution has a limited range of acceptable head levels of the water. By taking advantage on the Malaysia household water pressure standard for mains water pressure, which is ten meters per head (or 1 bar), the water pressure should be strong enough to fill 4.5 litre (one gallon) container in 30 seconds from a ground floor tap. This is the minimum level of pressure for each house to receive although the pressure can be higher [5]. Thus, when combined with the simple necessary parts, the Pelton turbine stands out as the best design

With the Pelton turbine selected, the question then becomes what is the best approach is to implement one without using any expensive parts. The runner, as one of the most critical parts needs to be shaped so that water flowing past it causes it to spin driving the actual generator. A typical runner for a Pelton turbine looks like the image seen in Figure 3.6 below.

Figure 3.6: Typical runner for a Pelton Turbine.

Just like with the Kaplan turbine, a runner for a Pelton turbine is expensive to purchase directly. Fortunately, the concept of a shape which spins as the water moves past it is common and can be found in many existing items. The spoon can be altered to be roughly like the Pelton turbine runner as shown Figure 3.6. An example, spoon runner is shown in Figure 3.7 below.

Figure 3.7: Spoon Runner

With an encasing to channel the water and a runner to capture the mechanical energy, the next task is to convert the kinetic energy of the spinning runner into electrical energy. This can easily be done with any number of designs, and is a subject which has been covered extensively. Both AC and DC motors can be used as generators. Making a generator out of the requisite parts is also a possibility as the design is simple, and the necessary parts are inexpensive.

Upon inspection, however, it turns out that a permanent magnet DC motor is simple enough, and common enough, that buying a suitable fully assembled motor is actually inexpensive. Keeping in mind the amount of labour required to build an entire generator, it seemed much easier to simply buy appropriate models which are preassembled.

There are numerous sources of adequately sized DC motors, but the simplest seemed to just be used treadmill motors as they are inexpensive and designed to run at fairly high power levels. Thus, based on numerous number of available DC motor, a 12V DC motor has been selected based on their size and their power generated is suitable to be implemented in this project.

3.2.3 Hardware Design and Assemble

During this part, at the assembling of the hardware, the Pelton turbine that has been selected before, has been sketched by using SolidWorks. The design of the Pelton turbine has been influenced by the idea of using a metal spoon as a turbine to minimize the cost. The metal spoon is tied together with the plywood to strengthen the turbine. The Figure 3.8 and 3.9 below are shown the sketched and the testing turbine that has been assembled.

Figure 3.8: Turbine design by SolidWork.

Figure 3.9: Turbine after assembling.

The casing of the turbine also have been designed by using SolidWork in intention to stabilize the turbine when it is being used. The casing of the turbine is using the Acrylic Sheet Cast which can withstand the vibration and the impact of the turbine when water hit the turbine. The casing also has been strengthened by building a wood skeleton outside the casing so that it be a portable and hold the casing proper.

The hardware casing has been designed wider and smaller on the lower part so that it can flow out the running water freely into the out coming of a household water pipe. This design of the casing has been finalized after being considered with the previous design that will cause water to accumulate in the casing and do not flow well. The design of the turbine casing is shown as Figure 3.10, 3.11, 3.12, 3.13 and 3.14 below.

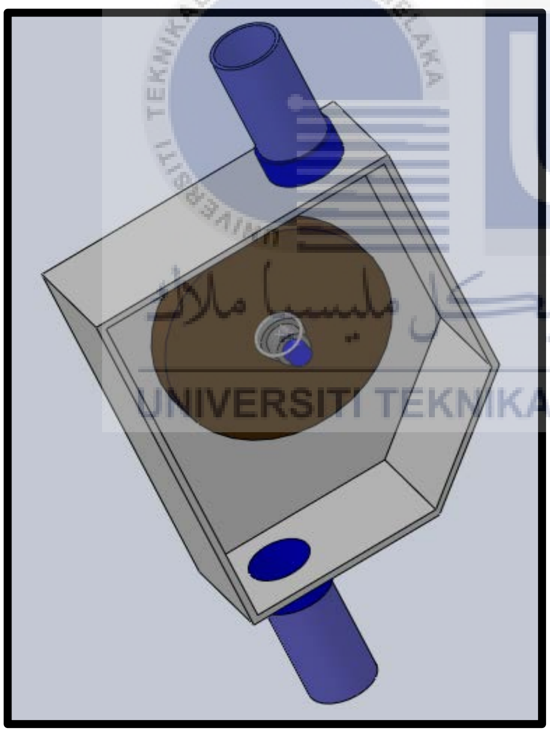


Figure 3.10: Casing of the turbine by SolidWork

Figure 3.11: Casing with the wood skeleton of the turbine by SolidWork

Figure 3.12: Turbine Front View

Figure 3.13: Turbine Back View

Figure 3.14: Turbine Side View

As the generator have been driven to rotate and produce the electrical energy from the turbine, the 12V DC motor has been selected to fulfil the requirement. This model, reaches 12V at 4850 RPM. The Figure 3.15 below shows the motor that as been used during the project.

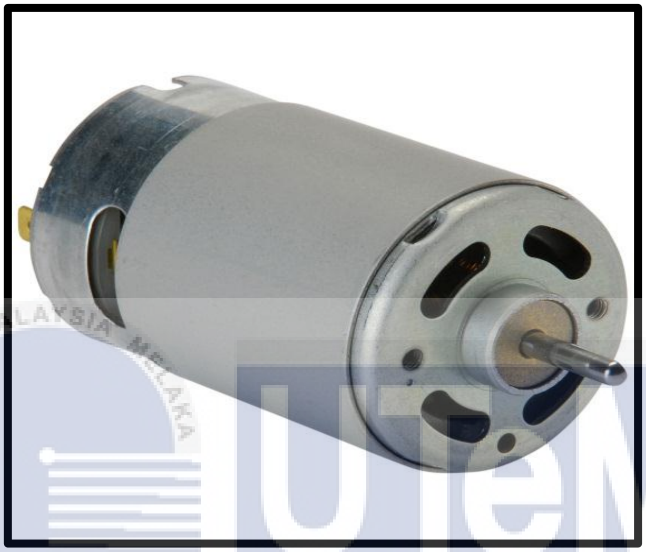


Figure 3.15: 12V DC Motor

As the project is to analyse the power that generate from the turbine by varying the shape of the incoming of household water pipe, the early design that will considered as the test shape has been drawn by SolidWorks as the Figure 3.16, 3.17 and 3.18 below.

The test shape of the incoming water household pipe is divided into three shapes;

1. Original shape
2. Baffle shape
3. Nozzle shape

The test shape will affect the flow rate of the water that will flow through the turbine and causes the turbine to rotate faster or vice versa.

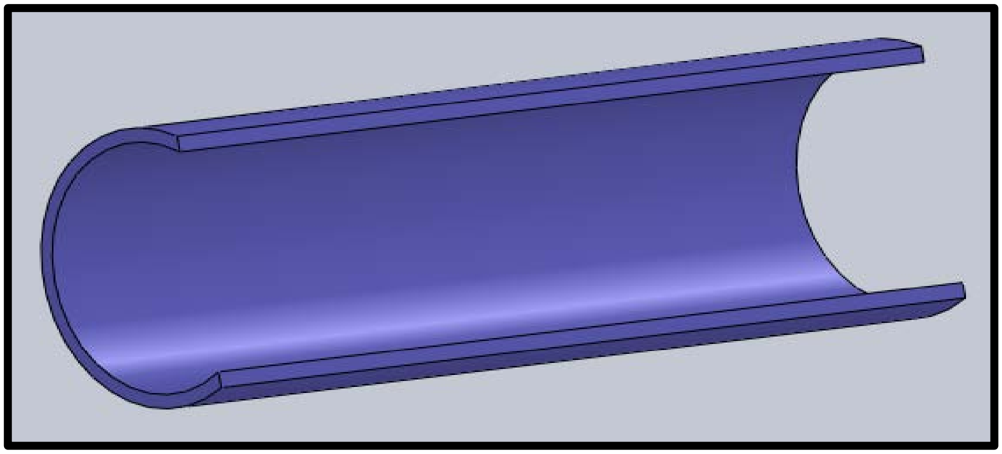


Figure 3.16: Original Test Shape by SolidWork

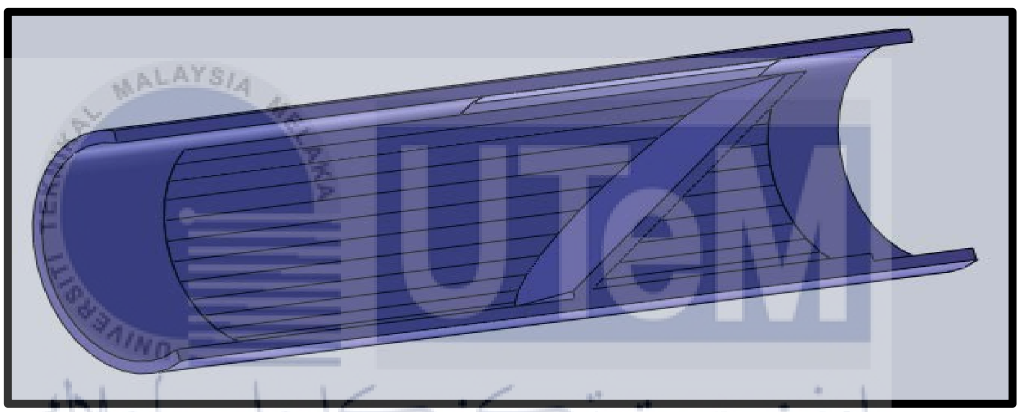


Figure 3.17: Baffle Test Shape by SolidWork

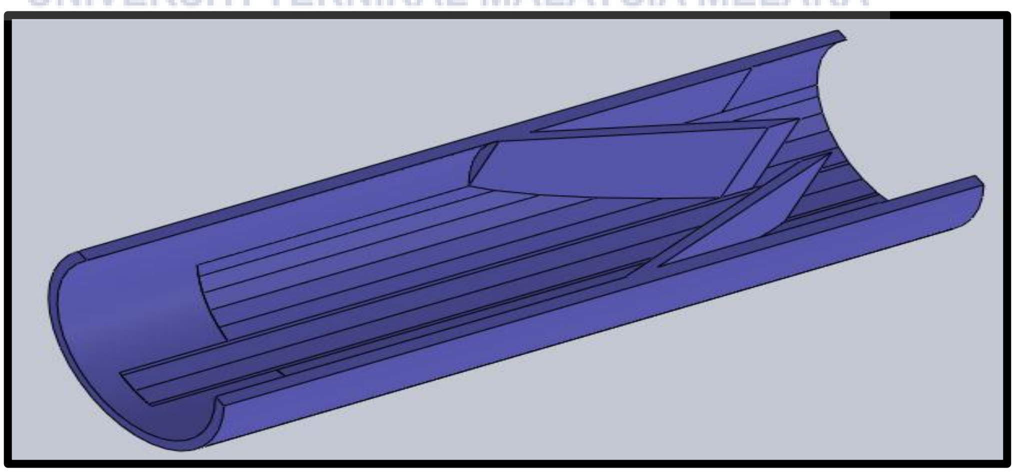


Figure 3.18: Nozzle Test Shape by SolidWork

3.2.4 Testing

The testing will be conducted under a condition that will comply with the household water pipe assembling. As stated at the scope of the project, the type of head to test the turbine is a low-head type which is matched with the water tank in a house. The hardware will be tested with varying the shape of the incoming water pipe as mention before. The height of the incoming water tank and the amount of water that will flow through the turbine will be fixed for each testing. The Figure 3.19 below shows the testing rig that has been used during the project.

Figure 3.19: Water Test Rig

The water test rig has been built based on experimental studies done previously and some modifications have been done to meet the objectives set for this project. Figure 3.17 shows the arrangement of the testing rig. The framework for this testing rig that supports the weight of the water tank with is made by rectangular steel tube size 600x800mm. While for the water storage tank sized 31” x 41” x 41” (length x width x height) with 100 gallon capacity was made of Polypropylene material. On the penstock system, the water from the storage tank flow through the penstock made from PVC pipes sized 1” and flow through the testing pipe to the turbine.

The water flow from the tank (reservoir) with a head of 4 meters and fixed pressure recorded as 6 psi. The flow rate supplied to the turbine can be controlled using a control valve on the main supply line. Mechanical water meter (operates between 9-190 LPM) were installed after the control valve on the supply line to measure the actual flow through the turbine.

Referring to Figure 3.20, it can be seen that the arrangement of the Pico hydro generator system. All water connections which are the penstock, water meter and turbine will be sealed to prevent the inefficiency of the electrical generate. At the end of the generator system, there will be the Pelton turbine that drive a shaft connects to DC motor and this is where the electrical charge will be generated.

The length of the pipeline for the system can vary widely depending on the distance between the water source and the turbine. The outlet pipeline diameter may range from 0.5 inches and it is large enough to handle the amount of water flow. Losses due to friction need to be minimized to maximize the energy available for conversion into electricity. This type of turbine is a universal turbine and it suit for low head with low water flow rates applications and only requires very little maintenance.

The permanent magnet DC generator will generate the current based on the shaft speed. The generator shaft is jointed with the small scale turbine and the voltage wire of DC generator is connected to the DC voltage battery. The permanent magnet is more efficient since no power is wasted to generate the machine magnetic field. It is also not susceptible to armature reaction, thus the field strength remains constant. The permanent magnet generator’s ring and magnet assembly are considerably smaller in diameter than its wound field counterpart, providing substantial savings in both size and weight.

From DC motor, there are two wires that connected directly to the DC Booster circuit that will stabilize the voltage into 5V DC so that it is suitable to be used with the small electrical appliances such as smart phone and battery bank.

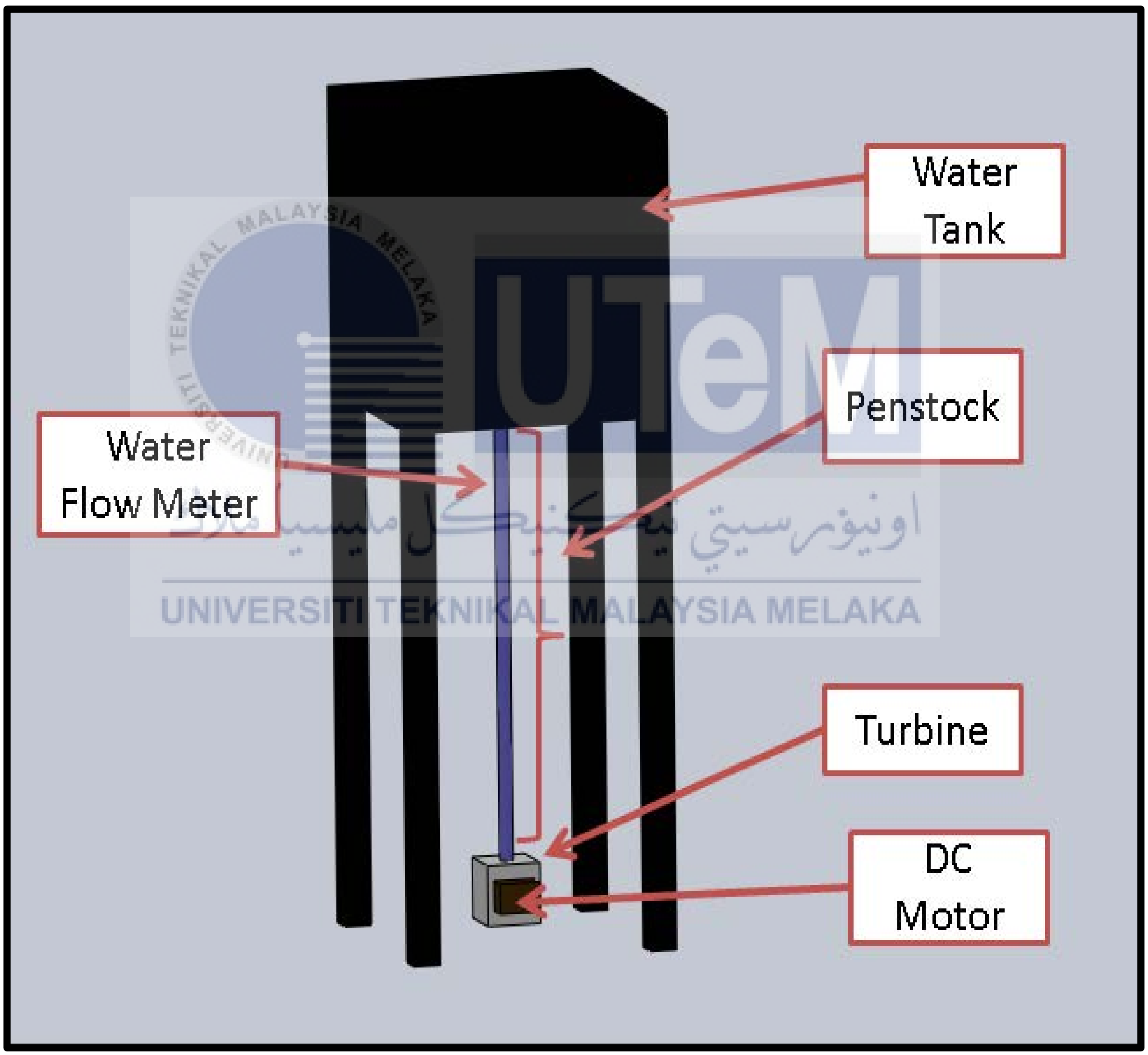


Figure 3.20: Pico hydro turbine arrangement

3.2.5 Calibration and analysis of hydro turbine

After assembling the hardware and testing, the analysis will be conducted to determine the best shape of the incoming water pipe for the Pico hydro turbine. The best shape of the incoming pipe will produce a better value in rotational speed producing from the Pico hydro turbine.

The test conduct between those three different shapes of the incoming water pipe. The test is conducted under five repeated tests to analyse the consistency of the turbine under the testing object.

3.2.6 Report writing

The report writing will be conducted together with the final presentation after the result of the analysis is obtained. The findings of the proposed research will be documented in technical papers and research report for publications.

CHAPTER 4

RESULT AND DISCUSSION

To achieve the goal, a separate analysis of the data set is conducted to determine the parameters needed to obtain for the optimum test shape of the incoming water pipe.

4.1 Results

Three different test shape of incoming household water pipe is set to be variable input parameter to observe the behaviour of the parameter output. The selection of the optimum test shape of the incoming water pipe is based on the power output with high current as it is required to charge the battery more quickly. The testing is conducted by taking the flow rate of the water and rotational of the turbine under 30 seconds and five consecutive repeated tests. The table 4.1, 4.2 and 4.3 below shows the result of the test under three different shapes of incoming household water pipe.

Table 4.1: Original shape result.

Test	Flow Rate (Q)	Turbine Rotational Speed (RPM)	DC Voltage (V)
1	55.5	415	1.09
2	55.1	414	1.09
3	53.9	412	1.08
4	56.2	415	1.09
5	57.7	417	1.10

Table 4.2: Baffle shape result.

Test	Flow Rate (Q)	Turbine Rotational Speed (RPM)	DC Voltage (V)
1	52.8	371	0.97
2	51.6	370	0.96
3	49.4	369	0.96
4	49.4	369	0.96
5	52.6	373	0.98

Table 4.3: Nozzle shape result.

Test	Flow Rate (Q)	Turbine Rotational Speed (RPM)	DC Voltage (V)
1	49.5	350	0.91
2	48.9	350	0.91
3	50.3	353	0.92
4	49.4	351	0.91
5	48.7	350	0.91

4.2 Test Results Discussion

Based on the data collected, several graphs have been drawn to show the relationship and comparison of several performances. During the test, the flow rate and turbine rotational speed are measured in 30 seconds. In addition, the rate of water flow will also be taken as measuring factor in this experiment. From the equation (4.1), the water pressure for this experiment can be determined according to the water head.

$$P = H / 0.704 \qquad \textbf{(4.1)}$$

Total water used for 30s is also recorded by using a water meter to calculate the flow rate of the water. The flow rate of water is not the same depending on the test shape of the incoming water pipe. Equation (4.2) also will be applied to determine the flow rate of the turbine. The voltage reading for each shape can be calculated by using the ratio between the turbines rotational speeds with the DC motor RPM as stated in equation (4.3).

$$Q = V/30s \qquad \textbf{(4.2)}$$

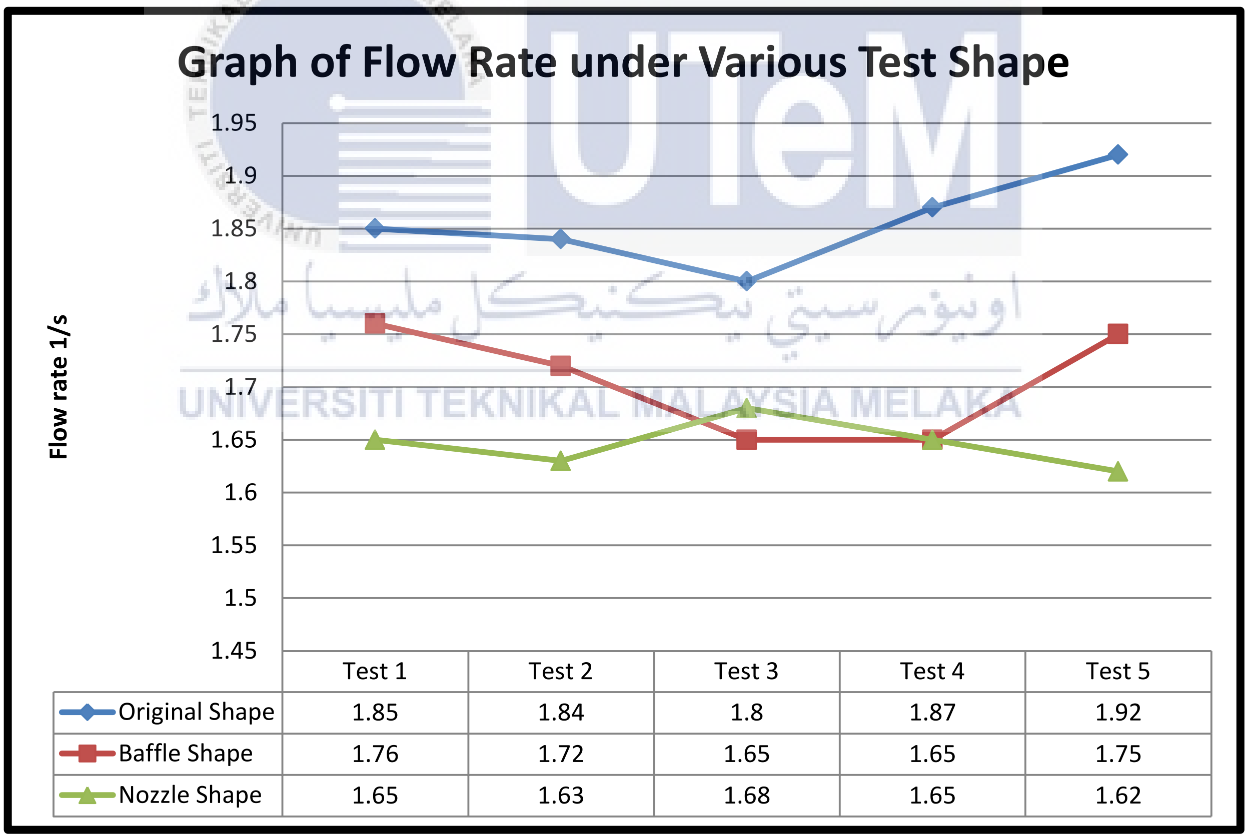
$$4850 \text{ RPM} : 12\text{V} \qquad \textbf{(4.3)}$$

The table shows the reading of rotational speed (RPM), water flow rate (l/s) and DC voltage as it measured by a varying the test shape of the incoming water pipe. The test is run with 4m head and using DC-12V Permanent Magnet Motor as a generator for this system. The data of the parameter present are the average value from 5 repeated readings.

4.2.1 Flow Rate Results Discussions

The graph based on Figure 4.1 below shows same pattern which has gradually increased until it reach the optimum point. The original test shape shows its use the higher flow rates compare to the baffle and the nozzle test shape. The maximum flow rate recorded is 1.92 l/s for the original test shape and 1.76 l/s for the baffle shape while the nozzle shape has 1.68 1/s for its maximum reading.

An average different of flow rate for original test shape is 1.86 1/s which is larger compared to baffle and nozzle which is 1.70 1/s and 1.65 1/s.



	Test 1	Test 2	Test 3	Test 4	Test 5
Original Shape	1.85	1.84	1.8	1.87	1.92
Baffle Shape	1.76	1.72	1.65	1.65	1.75
Nozzle Shape	1.65	1.63	1.68	1.65	1.62

Figure 4.1: Graph of Flow Rate under Various Test Shape

4.2.2 Turbine Rotational Speed Results Discussion

From the graph shows in Figure 4.2, it is clear that the original shape has the higher angular velocity compared to the baffle and nozzle shape. The maximum velocity for this experiment is 417 RPM under the original shape and the minimum velocity recorded is 350 RPM which is the data from nozzle shape. From this data it can be concluded that the flow rate of the water has affected the result of the velocity of the turbine.

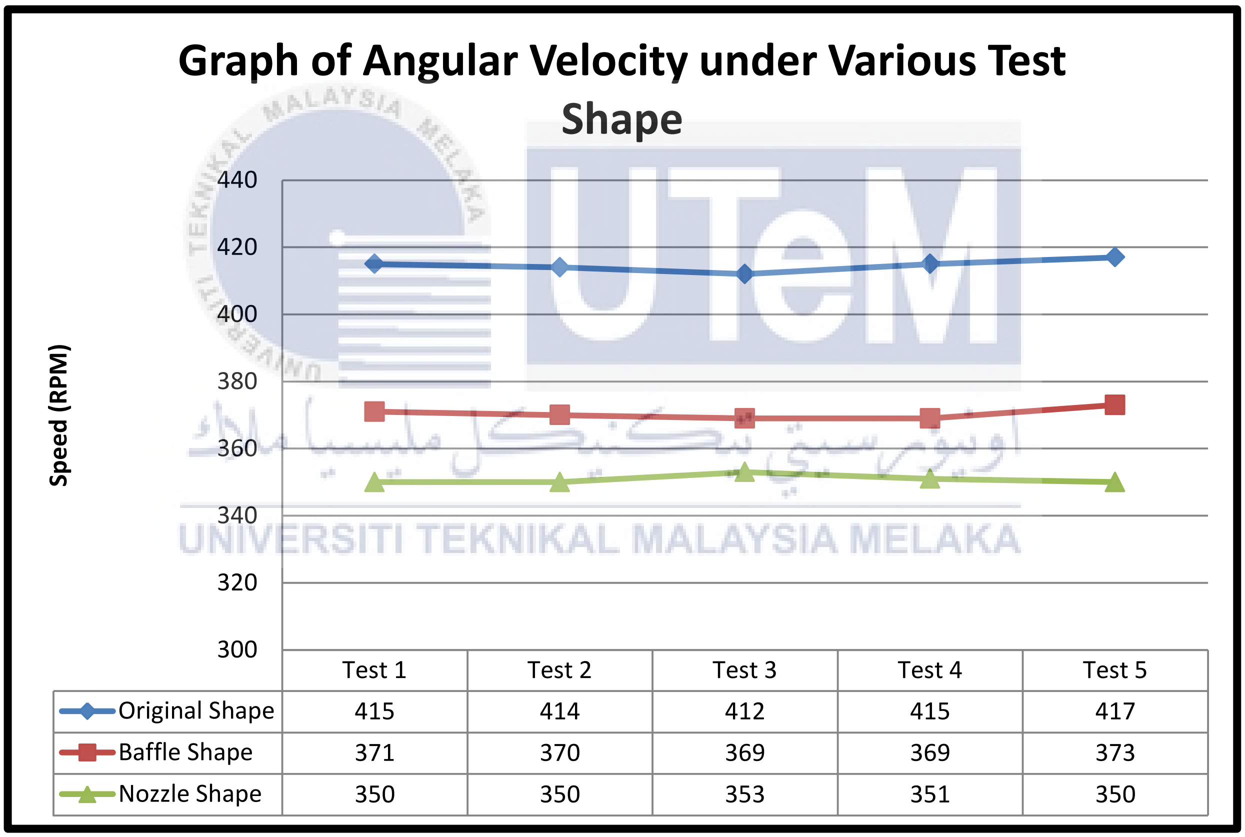
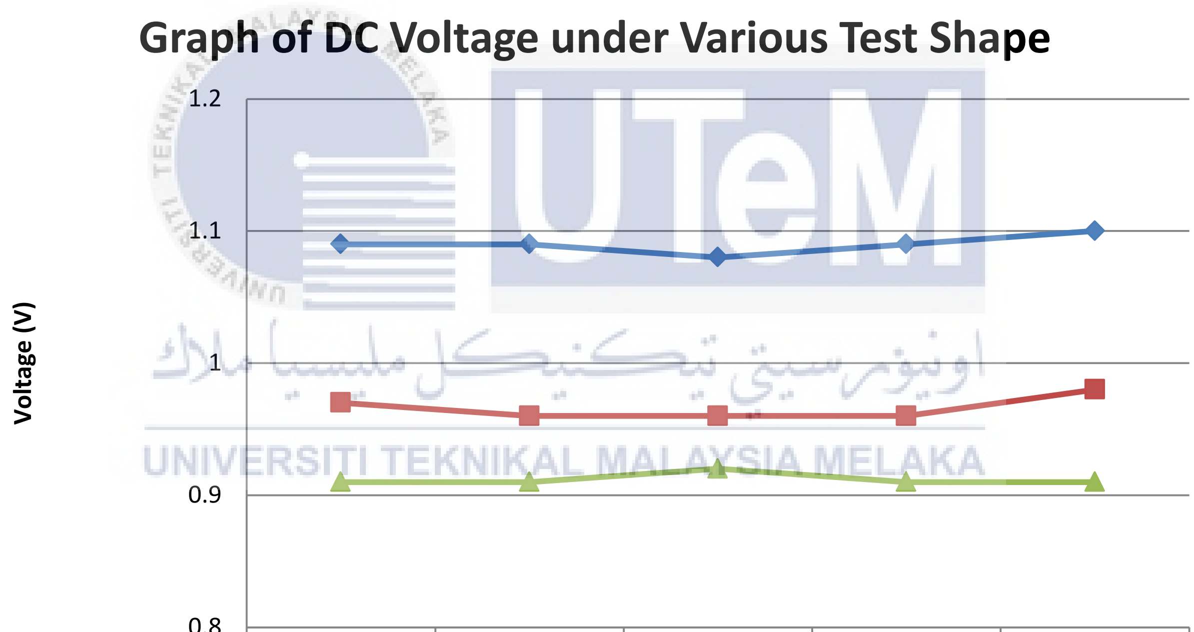


Figure 4.2: Graph of angular velocity under various test shape

4.2.3 DC Voltage Results Discussion

The graph shows below in the Figure 4.3 are the comparison of DC Voltage output of the original shape, baffle shape and the nozzle shape. It is clearly we can see that the DC Voltage output of the original shape has the largest output compare to others. When comparing to each shape, the original shape has large differences between each shape which is illustrated by the huge gap between the line compare to the baffle shape and the nozzle shape size which the gap is smaller which mean less different.



	Test 1	Test 2	Test 3	Test 4	Test 5
Original Shape	1.09	1.09	1.08	1.09	1.1
Baffle Shape	0.97	0.96	0.96	0.96	0.98
Nozzle Shape	0.91	0.91	0.92	0.91	0.91

Figure 4.3: Graph of DC Voltage under Various Test Shape

4.3 Hardware Portability and Cost Discussion

As the objectives of the project are to develop a low-cost and portable Pico Hydro turbine, the size and the cost must be our main concern in assembling the hardware. Thus, the size of the turbine, including the casing must be designed at smaller size with a reliable, affordable, economically viable and socially acceptable to ensure it will produce a smooth mechanical rotation and output. The Figure 4.4 below shows the specification of the turbine with the exact size.

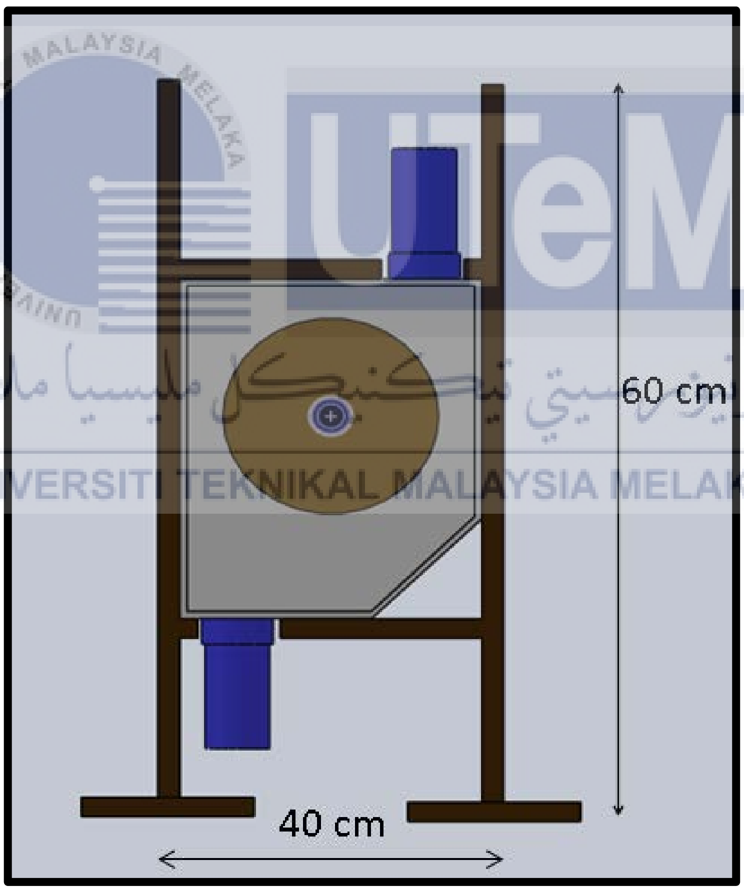


Figure 4.4: The size of the Pico Hydro Turbine

The cost of the turbine will be compared based on the size of the turbine that had been assembled with the ready-made turbine in the market. The turbine that available in the market based on ebay, will be compared based on their price in the table below. From the table 4.4 below, it can be concluded that the turbine use is far cheaper in cost compared to the other turbine available in the market at the same size.

Table 4.4: Pelton Turbine Comparison

Turbine	**Pelton turbine used during the project**	**Pelton turbine available in the market**
Image		
Price	Plywood: RM 5 Metal Spoon: RM 3 Total: RM 8	US $34.60 x RM 3.57 Total: RM 123.52
Size	30x30cm	30x30cm

CHAPTER 5

CONCLUSIONS

This section examines the conclusion and recommends future work to further enhance the improvement of the framework. It additionally focuses on the importance and potential application from the research output.

5.1 Conclusions

Analysis of performance of Pico hydro turbine using low head (4m) and low flow water resources is conducted by applying several methods that have been discussed in the methodology. The performance of the Pico hydro turbine is influence by several parameters which is head, flow rate and the shape of the incoming water source. From the collected data, it proves that at the constant water head (4m) the Pelton turbine spin faster when using the original shape of incoming water pipe compared to the baffle and the nozzle shape. Therefore, the cost of the turbine will be reduced by using the original shape compared to the custom made shape.

The Pelton turbine, which is has been made from the metal spoon shows a good potential to be used for a low head condition. The Pelton turbine also proves that it can perform well even it fabricated from a lower cost. Given enough head and flow rate, this low cost turbine can provide enough power to supply any small electrical appliances, thus it will be big enough to provide green sustainable energy using Pico Hydro technology.

5.2 Future Recommendation

The weakness and limitations of the project have indicated the following areas as recommendations for further work.

- The size of the turbine.
    - Minimize the size of the turbine and the casing by taking the weight of the turbine into account.
    - Design a new turbine so that it can be fit into any situation such as during a very low water flow in the system.

- The material used.
    - Design with lighter material for the turbine part.
    - To increase speed and become more portable.

- The power loss.
    - Install a battery bank into the system to avoid the power loss.

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