PIPE NOZZLE DESIGN EFFECT TO THE SPEED OF TURBINE AND OUTPUT VOLTAGE OF THE PICO-HYDROPOWER GENERATOR SYSTEM

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Thesis submitted in fulfillment of the requirements
for the award of the degree of the
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“Thank you” and “Sorry” is the simplest but powerful word which we learnt it since nursery school, but nowadays these words were not easy to be talked and heard just because we are already as a teenager.

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ABSTRAK

Tenaga boleh diperbaharui banyak dipromosikan dan digunakan di seluruh dunia. Di Malaysia, loji tenaga hidro dan janakuasa turbin angin hanya dibina dalam skala besar, seperti Stesen Janakuasa Sultan Mahmud (Empangan Kenyir) dan Bakun Dam. Loji hidro tenaga simpanan pam terbesar di dunia terletak di Virginia di Amerika Syarikat, ia dapat menghasilkan sekitar 3003MW elektrik untuk memulihkan masa permintaan. Idea utama sistem penjana Pico-Hydropower ini adalah dari loji kuasa hidro simpanan pam dan pemasangan panel solar di atas bumbung rumah di Malaysia yang disebut cleantech solar dan dipromosikan oleh pakar PV dan Tenaga National Berhad (TNB). Dari projek cleantech solar, kami mempunyai idea utama elektrik boleh dihasilkan di rumah dan dijual kembali kepada peniaga sebagai keuntungan yang dapat dijimatkan. Dalam tesis ini membahas kajian mengenai kesan reka bentuk paip terhadap voltan keluaran sistem penjana Pico-Hydropower. Objektif utama projek ini adalah merancang sistem penjana pico-hidro kuasa rendah dan mudah dipasang untuk rumah. Objektif kedua projek ini juga adalah untuk menguji jenis dan kapasiti beban yang akan dibekalkan oleh tenaga hidro pico dan prestasi sistem penjana tenaga elektrik Pico yang dibangunkan dari segi Daya (W), Voltan (V) dan Arus (A). Turbin adalah bahagian penting dalam sistem penjana kuasa hidro. Reka bentuk turbin dapat mengubah hasil keluaran sistem penjana kuasa hidro. Pelton turbine dan Turgo turbin adalah kategori turbin impuls kedua turbin ini lebih sesuai untuk dimasukkan ke dalam sistem penjana Pico-Hydropower ini, kerana tekanan air, tinggi, dan ukuran reka bentuknya. Seterusnya, reka bentuk kepala paip juga penting. Kepala paip (muncung) dapat mempengaruhi prestasi sistem penjana Pico-Hydropower, kerana keterbatasan air untuk mengisi tangki air tertentu, kita harus menggunakan jumlah maksimum air dan waktu untuk memiliki kinerja yang terbaik dalam sistem penjana. By the way, turbin dicetak oleh pencetak 3d dan menggunakan filamen PLA. Filamen PLA yang digunakan kerana ia lebih komersial dan lebih murah jika dibandingkan dengan filamen yang lain. Filamen PLA dapat membentuk produk tahan hentaman tinggi yang lebih sesuai dengan sistem penjana Pico-Hydropower dan turbin impuls. Paip dalam fabrikasi prototaip ini menggunakan pencetak 3d kerana kita dapat memiliki bentuk dan ukuran yang dapat disesuaikan dan menghasilkan hasil yang kasar. Kelemahan penggunaan pencetak 3d dalam sistem perpaipan adalah permukaan kasar dalam paip akan mempengaruhi hasil output berbanding dengan permukaan paip PVC atau poli yang jernih. Akhirnya, turbin dan paip Pelton dalam fasa 30 darjah dan nisbah 3 dilaksanakan dalam sistem penjana kuasa hidro Pico.

ABSTRACT

Renewable energy widely promoted and used worldwide. In Malaysia, hydropower plant and wind turbine power plant only built in a large scale, such as Sultan Mahmud Power Station (Kenyir Dam) and Bakun Dam Power Plant. The world largest pumped storage hydropower plant is located at Virginia in USA, it can produced around 3003MW of electric to recover the demand time. The main idea of this Pico-Hydropower generator system is from the pumped storage hydropower plant and installation of solar panel on the rooftop of houses in Malaysia which called cleantech solar and promoted by PV expert and Tenaga National Berhad (TNB). From the project of cleantech solar, we have the main idea of electric can produced in houses and sell back to the dealer as a profit to be save. In this thesis deal with the study on the pipe design effect to the output voltage of the Pico-Hydropower generator system. The main objective of this project is design a low cost and easy installed pico-hydropower generator system for houses. The second objective of this project also is to test the type and capacity of loads to be supplied by the pico-hydropower and the performance of the developed Pico-Hydropower generator system in terms of Power (W), Voltage (V) and Current (A). Turbine is an important part in the hydropower generator system. The design of the turbine can changed the output result of the hydropower generator system. Pelton turbine and Turgo turbine is the categories of impulse turbine both of this turbine more suitable to implement into this Pico-Hydropower generator system, due to the water pressure, high, and size of design. Next, the piping head design is also important. The pipe head (nozzle) can affect the performance of the Pico-Hydropower generator system, due to the limitation of water to fill up the specific water tank, we have to use out the maximum number of water and time to have a greatest performance in the generator system. By the way, the turbine was printed by the 3d-printer and used the PLA filament. PLA filament used due to it is more commercial and its cheaper compare to the other filament. The PLA filament can form a high impact resistant product which more suitable to the Pico-Hydropower generator system and the impulse turbine. The pipe in this prototype fabricate used the 3d-printer because we can have a customize shape and size and have a roughly result. The disadvantage of use the 3d-printer in piping system is the rough surface in the pipe will affected the output result compare to the clear surface of the PVC pipe or poly pipe. Finally, the Pelton turbine and pipe in 30degree phase and ratio of 3 implemented in the Pico-hydropower generator system.

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LIST OF ABBREVIATIONS

PHP	Pico Hydropower
HPP	Hydro Power Plant
ITs	Impulse Turbine
RTs	Reaction Turbine
PT	Pelton Turbine
TG	Turgo Turbine
SPAN	National Water Service Commission
FIT	Feed in Tariff
TNB	Tenaga National Berhad

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Water, is the most mysterious item in the universe. 71% of earth was covered by water, but some country still lacks of clean water to be consumed. Water as a natural and renewable resource other than sunlight and air. Hydropower plant could be one of the most prospect in the green energy level. At the end of year 2018, the electricity generated by hydropower plant was covered 15.8% of all the electricity generated around the world, it has occupied the highest percentage in the renewable electricity generated. (Figure 1.1.2) [1] According to the researched by National Water Service Commission (SPAN), Malaysian consumed average 201 litres of water used per person per day.

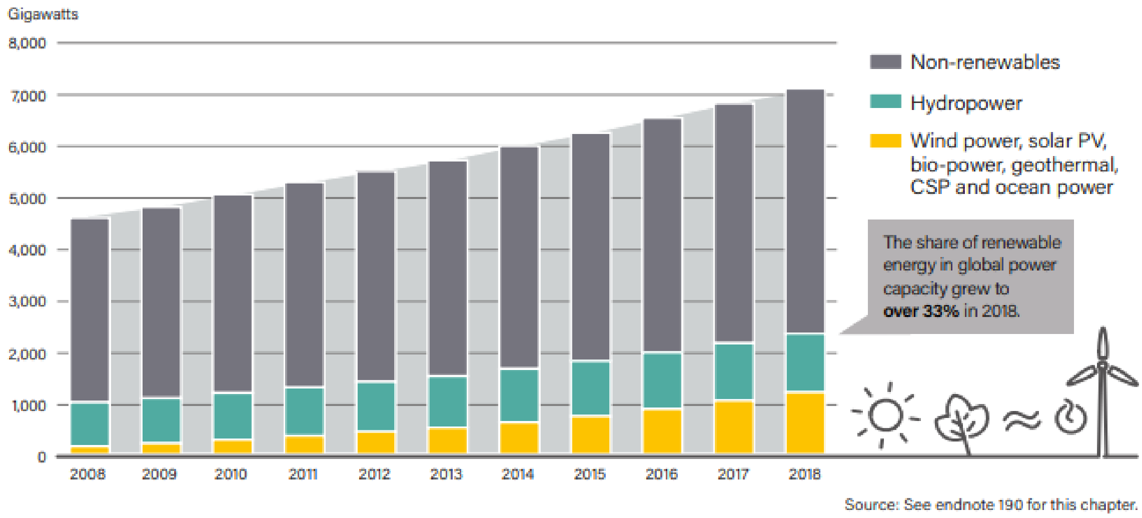


Figure 1.1 Global Power Generating Capacity, by Source, 2008-2018 [1]

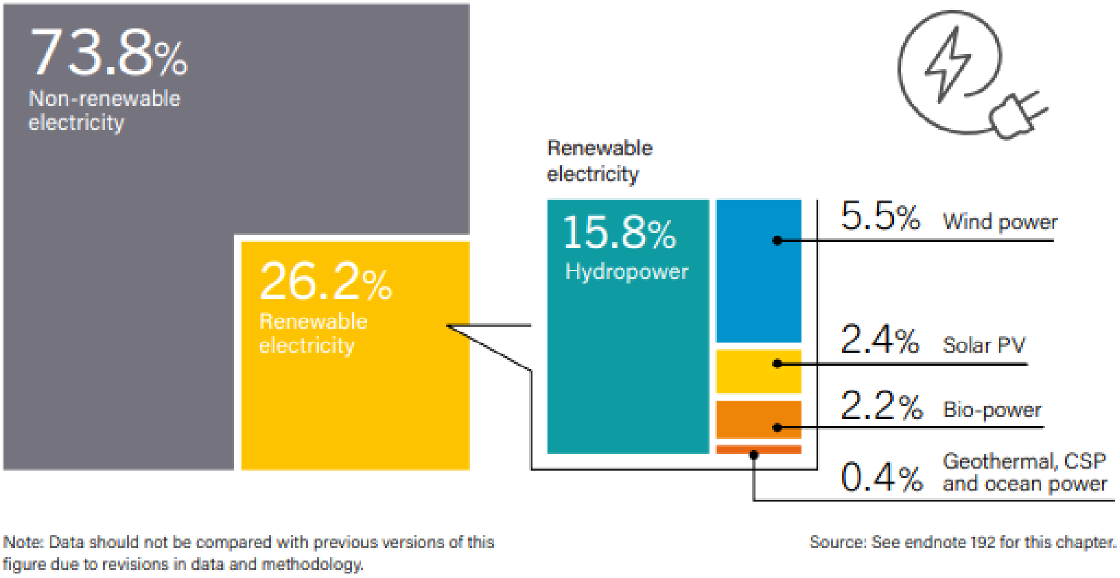


Figure 1.2 Estimated Renewable Energy Share of Global Electricity Production, End-2018 [1]

Hydropower can be categorized into three categories which is impoundment, run-of-river, and pumped storage hydropower plant. Pumped storage hydropower plant as the main reference to set up the prototype due to the characteristic and similarity of the working principle between of them.

The first type is the most common type of hydropower plant used a man-made dam on a river to store water in a reservoir. [2] It also called as an Impoundment hydropower plant since they store water for later consumption. The generating station are located at the dam toe or further downstream, connected to the reservoir through tunnels or pipelines. (Figure 1.1.3) The type and design of reservoirs are decided by the landscape and in many parts of the world are inundated river valleys where the reservoir is an artificial lake. In geographies with mountain plateaus, high-altitude lakes make up another kind of reservoir that often will retain many of the properties of the original lake. For example, in Scandinavia, natural high-altitude lakes are the basis for high pressure systems where the heads may reach over 1,000 m. One power plant may have tunnels coming from several reservoirs and may also, where opportunities exist, be connected to neighbouring watersheds or rivers. The design of the HPP and type of reservoir that can be built is very much dependent on opportunities offered by the topography [3].

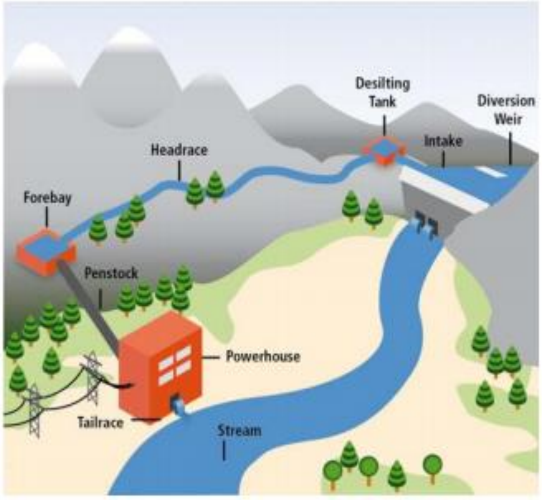


Figure 1.3 Impoundment Hydropower Plant (Storage Hydropower Plant) [3]

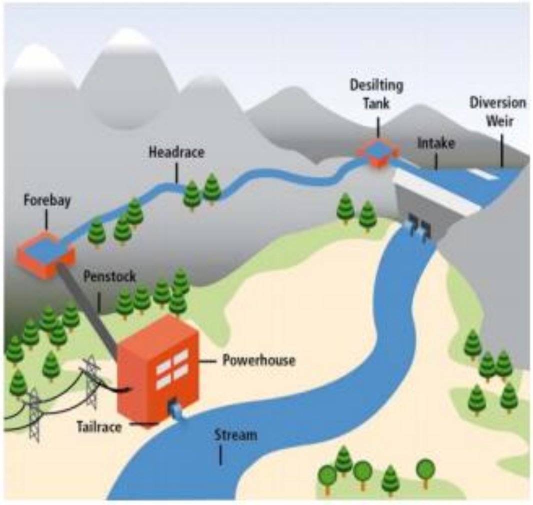


Figure 1.4 Run-of-River Hydropower Plant (Diversion) [3]

The second type is Run-of-River hydropower plant. A Run-of-River hydropower plant also known as run-of-the-river is where little or no water is stored or dammed. Because of no water storage, it is subjected to sustainable daily, monthly or seasonal variation, thus the plant will operate as an intermittent energy source. Such a hydropower plant may include some short terms storage (hourly, daily), allowing for some adaptations to the demand profile, but the generation profile will to varying degrees be dictated by the local river flow conditions. In a run-of-river hydropower plant, a portion of the river water might be diverted to a channel or pipeline (penstock) to convey the water to a hydraulic turbine which connected to an electricity generator. Figure 1.4 shows the installation of run-of-river hydropower plant is relatively inexpensive and such facilities have, in general, lower environmental impacts than similar-sized storage hydropower plants [2,3].

The third type is Pumped Storage Hydropower Plant. The pumped storage hydropower plant works like a battery, which its system pumped the water from the lower reservoir into upper reservoir, usually during off-peak hours, while flow is reversed to generate electricity during the daily load period or at other times of needed. Although the losses of the pumping process make such a plant a net energy consumer overall, the plant is able to provide large-scale energy storage system benefits. (Figure 1.5) [2,3]

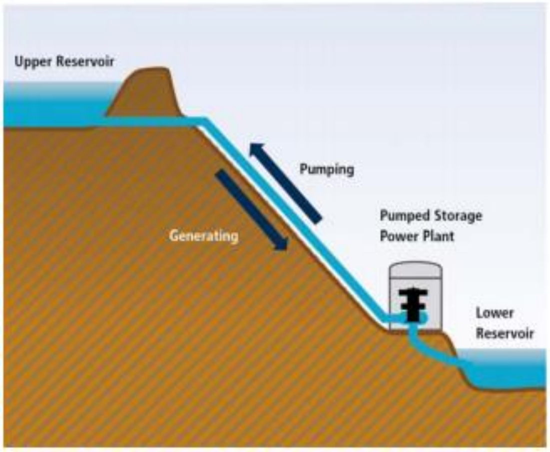


Figure 1.5 Pumped Storage Hydropower Plant (PSH) [3]

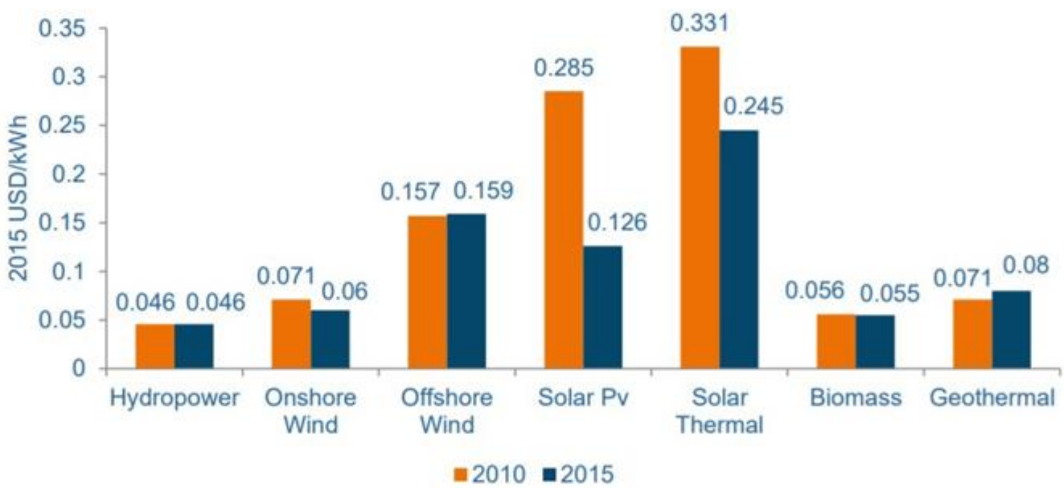


Figure 1.6 Cost of energy taking in year 2010 and year 2015 by LCOE [4]

Figure 1.6 shows that the construction fees and the maintenance fees for the solar power plant is higher than the hydropower plant, due to this statistic, we can ensure that the profit of the solar power plant will less than the profit of the hydropower plant. In the year of 2011, Feed-in Tariff (FIT) launched to Malaysia and it bring a new phenomenal to the renewable energy resource in Malaysia. Feed-in Tariff (FIT) have cooperated with Tenaga National Berhad (TNB) which is Malaysia largest electrical company in west Malaysia [4].

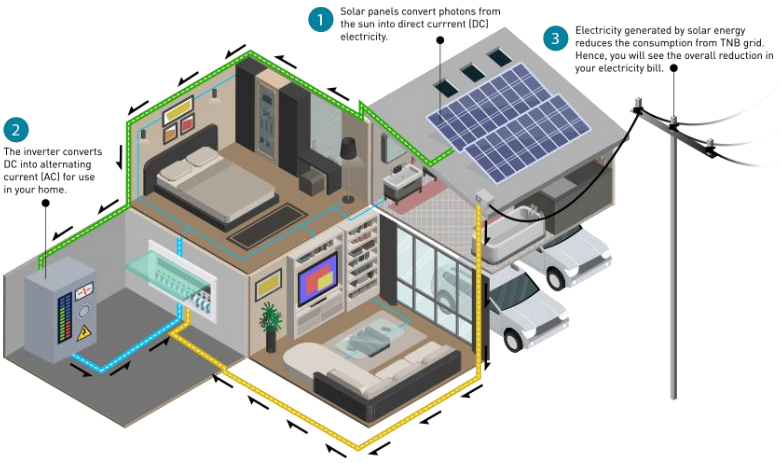


Figure 1.7 Feed-in Tariff by TNB [4][6]

The high expenditure and adverse environmental concerns that associated with the use of large HP plants have helped to focus the attention on small or Pico-scale HP plants, which reduce these affects considerably. Pico hydropower (PHP) offers an efficient, reliable and cost effective of alternative power sources. In addition, the demand for PHP in the market shows that PHP is the best and low-priced choice for rural or remote area electrification in developing nations. Nevertheless, the PHP technology is still considered as a brand-new in Malaysia. As of 1st October 2014, total generated capacity of power in Peninsular Malaysia stood at 21,060 MW, 52% of total power was generated by Tenaga National Berhad (TNB, the only electric utility company in Malaysia and the largest in ASEAN), while the remainder (48%) was generated by independent power producers (IPPs) [5].

Most of the water tank located at the rooftop of the house, this is because it can use the gravitational forces to maintain a high speed of water flow and provided to consumer without using a water pump. The type of turbine will directly affect the performance of the hydropower plant. The water in to the water tank it will has an impact, this will be caused to choose an impulse turbine as our references.

1.2 Problem Statement

1.2.1 Installation cost and location of pico-hydropower plant

Year 2011, Malaysia enacted the Renewable Energy Act. The scheme is managed and administered by the Sustainable Energy Development Authority (SEDA) of Malaysia. [4] Feed-in Tariff (FiT) was installed a solar panel at the rooftop of a house. The installation fees for a terrace house is around RM 19,000. [6] Besides that, most of the Pico-hydropower system installed at river and waterfall. For instant, the different part of the river or waterfall has different flow rate at the same time it will produced an unstable voltage supply to maintain its operating. [7,8] For example, pico-hydropower system unsuitable to install at the country which has dry season and winter season. Besides that, the different section of the river it has a different water flow rate. The different flow rate will affect the type of turbine used to get the best performance of the pico-hydropower system. [9] First problem in this thesis is the cost and location to install a pico-hydropower in house water tank is less than RM 600.00 it is cheaper compared to the PV panel and the location to be installed and maintenance is easier than the PV panel.

1.2.2 Water Pipe Nozzle ratio design

Water system piping consists of pipes, valves, fittings, pumps and associated appurtenances that make up water transportation system. [10] In volumetric machinery, the flow is confined to one or more compartments of variable size. The change in volume can be achieved through a movement of alternative translation or rotation and the compartments can remain at a fixed position or move up along the machine. [11] Pipe enlargement and reductions contribute to head loss that can included in minor losses. [12] In this part, we will focus on the design of the pipe based on the flow rate of the water input. The velocity of the water effect to the rotation turbine of the pico-hydropower generator system.

1.3 Project Objective

The main objective of this thesis is to developed a low cost and highly efficient Pico-Hydropower Generator System (PHP) by the flow water of the house water tank. To accomplish this, the following objectives must be achieved:

1. To design a movable, easily install and low costs Pico-Hydropower Generator system for house water tank to supply power for charging purpose.
2. To study and design of the piping system and the nozzle.
3. To study the efficiency of the piping system and 3d-printed nozzle using PLA filament.
4. To study the performance of the developed Pico-Hydropower system in terms of Power(W), Voltage(V), and Current(A).

1.4 Scope of Dissertation

The scope that are related to this project are:

1. To study focuses and designing a low-cost Pico-Hydropower Generator system that can produce power supplied to charging phone and power bank.
2. Establishing a control system through Arduino to monitor the water level and control the water level in the water tank by solenoid water valve.

3. Utilizing a suitable piping system and nozzle to produce a most efficient Pico-Hydropower generator system.

1.5 Expected Outcome

The expected outcome of this project is that the Pico-Hydropower Generator system will charge the power bank. First of all, when the water tank is empty, the water level sensor will scan the water level and it will send a pulse to Arduino UNO and the Arduino will open the solenoid valve to let the water in. Next, the water in will hits the turbine and the turbine connected with the PMA brushless DC motor by a gear will rotate and generated a power. The power will charge the battery or power bank. Besides that, when the water is fully filled the water tank, the water level sensor will send a pulse to stop the water into the water tank. In the expected output result, the nozzle with a ratio of 0.25 and have a 15degree slope more efficient than others nozzle.

1.6 Reality Outcome

The process of the pico-hydropower generator system is change from kinetic energy to electrical energy. In this process, there will be some energy loss have to included. First is the power loss, which according to research, the power generator has 50% of power loss in the process. Besides that, the nozzle was fabricated by 3d-printer and during the fabrication, the surface of the nozzle is rough than the PVC pipe. Moreover, some small power loss which is gear loss have to included due to the friction force of the pully between the gear and internal friction force of the DC-motor generator.

Furthermore, the efficiency of the turbine has affected by many factors. First is the design of the turbine, and this turbine is built by a 3D-printer, the surface of the turbine if rough, and it will cause a lots of friction force on the turbine. Besides that, the direction of the water to hits the turbine is also have a different to affected the efficiency of the turbine.

CHAPTER 2

LITERATURE REVIEW

In this chapter, we will discuss the historical background of the Pico-Hydropower, concept of the system, equipment, and some related works. Some examples, of the hardware and software that are used in this project will also be mentioned.

2.1 Historical Background of Hydropower

The waterwheel was invented in ancient Greece and Rome, and in the year 13 B.C., the Roman engineer and writer Marcus Vitruvius Pollio described a grain mill driven by a waterwheel and a cogwheel gear. Archeologists later proved the early existence of such drives of mills and of water-wheels used for the irrigation of fields [13]. Hydropower is one of the oldest methods that have been used by the human to produce mechanical energy instead of electrical energy because the generation of the hydroelectricity began only from the 19th century [15]. It is found that in the 19th century the water turbine has been used widely in industry in order to produce electricity [16]. The first invention of hydroelectric system based on waterwheel is started at the Wisconsin, USA in 1882. It was also being stated that in Fox River, some area in Wisconsin, there is the first moving wheel which is being used to generate electricity and it is trusted to be the first one in USA [15, 16].

2.2 Pico-Hydropower

In table 1 shows that, pico-hydropower plant is a hydropower plant generate electricity lower than 5kW. In many parts of the countries, almost 30 years various types of PHP technology have been used mostly for the rural electrification area, particularly in countries that have a high demand of electricity like China and other countries [17].

Table 1 Size of Hydropower [7]

Hydropower Categories	Power Range
Large	More than 100MW
Medium	25 – 100MW
Small	1 – 25MW
Mini	100kW – 1MW
Micro	5 – 100kW
Pico	Less than 5kW

2.3 Antirior Studies

2.3.1 Peltric Set

Peltric set is the combination of Pelton wheel with the electric generator, the generator was vertically mounted directly to the Pelton turbine, it is a useful water-powered turbine for the mountain regions where the available head is high but flow is low. This peltric set can be economically connected in an existing break pressure tank of a drinking water supply line. [18].

2.3.2 Off-grid electrification from Pico-hydro System in Kenya

Figure 2.1 Pico-hydro scheme using Pelton Turbine in Kathamba, Kenya [36]

Pico-hydro scheme based on Pelton Turbine has been designed and studied by researchers from Nottingham Trent University, United Kingdom. The system was installed in rural residential of Kathamba, Kenya. The overall scheme was able to generate up to 1.1 kW during operation with 8.41 m3 /s flow rate using Pelton Turbine with 200 mm pitch circle diameter [36].

2.3.3 Micro-hydro scheme in Bondo, Kenya

A micro-hydro scheme with Pelton Turbine is designed and installed at the river located in Bondo, Kenya by a team of researchers from University of Zimbabwe. They assessed that the system has a capacity of 88 kW during operation with 0.325 m3 /s flow rate. The overall efficiency of the turbine is measured at 60% [37].

Figure 2.2 Pelton Turbine used in micro-hydro scheme in Bondo, Kenya [37]

2.4 System Components

To complete the combination of PHP, many parts consists on it, such as;

a) Penstock

b) Nozzle

c) Turbine

d) Generator

e) Charging Circuit

f) Battery

g) Electrical Loads

2.4.1 Penstock

Penstock is the first part in the hydropower system, the penstock is a pipe used to delivers water from the reservoir or source of water to the turbine area. Penstock can used to control the water flowrate, speed, and velocity by changing its diameter. At the same time, when the penstock pressure is high, the walls of the penstock must be thick enough to withstand the maximum water pressure to avoid busting pipe at the critical environment. Besides that, the efficiency of the penstock depends on the material, length, and diameter of the pipe. The large diameter pipeline, the less friction occurs and more power can be delivered to the turbine but the cost will be more expensive. In this case, the flow rate of water is calculated by using bucket method with the equation below [19]:

$$Flow\ rate = \frac{Bucket\ Volume}{Time\ to\ fill\ the\ bucket} \tag{2.10}$$

2.4.2 Nozzle

Impulse turbine is different with the reaction turbine, to the reaction turbine normally used gravitational force to turn the turbine, but impulse turbine needed a force to turn the turbine and nozzle take a main character on it. There are many types of nozzles available in the world, and a suitable nozzle implemented to the PHP system have to pass through lots of experiment and calculation. Figure 1.8 shown the types of the nozzle normally used and founded in the market [19,20].

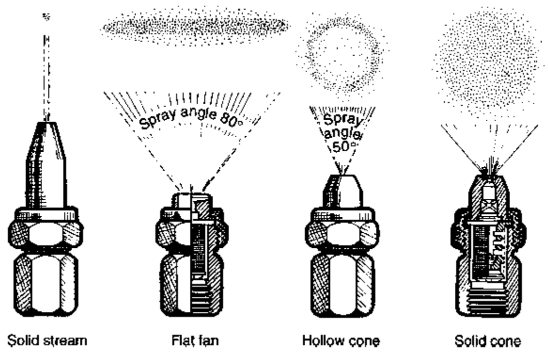


Figure 2.3 Types of nozzle in the market [19]

2.4.3 Turbine

Turbine is the heart of the hydropower system, the design of turbine will affect the performance of the PHP and the lifetime of the system to use. Turbine will convert the kinetic energy from the penstock to mechanical energy. There are various type of turbine and the selection of turbine depends on the head of water, water flowrates, and the location of the turbine implemented.

Table 2 Groups of impulse and reaction turbine [20]

Turbine Runner	Head Pressure		
	High	Medium	Low
Impulse	Pelton Turgo Multi-jet Pelton	Crossflow Turgo Multi-jet Pelton	Crossflow

Reaction		Francis Pump-as-turbine	Propeller Kaplan

Turbine can be classified by head pressure and the type of turbine runner, which had high head pressure, medium head pressure, and low head pressure and the turbine runner had impulse turbine (ITs) and reaction turbine (RTs) [20][21].

2.4.3.1 Classification of turbines

There are different types of impulse turbines , such as Turgo, Pelton and Cross-flow turbines. It is worth mentioning that design of ITs are simple and are low-priced [20]. Commonly impulse turbine is applied for high and medium water heads [21]. A Pelton turbine (PT) has one or multi-jets. PTs are commonly used in the PHP system due to its high efficiency [21]. Generally, a PT has high efficiency with rate of 70–90% [22]. PT can be operated with low water flow rate (Fig. 1) and can generate the power easily [23]. However, PT cannot be worked in the free flow of water resources. In order to get a high speed-jet in the PTs, the water must be drive from a nozzle [24]. When using the reaction turbines (RTs), the water flow is employed to produce an upward hydrodynamic force which rotates the blades of runner. Compared to ITs, the RTs showed an excellent performance in low-head and high-water flow sites. Under slow working speed, the efficiency of RTs is much higher than that of ITs [20].

A Francis reaction turbine is one of the most frequently employed turbine types for the HP stations [25]. It can be applied for large, medium or micro HP plants, as their working ranges are from 1 m to 900 m [26], while Propeller or Kaplan turbines are more suitable and productive for low-head sites [25,27]. Archimedeans screw turbine (AST) has become more attractive for lower-head sites, as its heads can be set as low as 1 m, besides it is good for sites with large water flows [28]. Western renewable energy [29] and Landustries [30] manufactured the AST as a comparatively innovative approach to generate electrical power from a low-head water source. The highly quality ASTs are capable to produce power/electricity throughout the year round 24 h/day. Water wheels

(WWs) have been utilized as conventional technology of producing hydroelectricity in small capacities for many years. Although WWs are less efficient than water turbines, however, WWs are considered an economical and practical choice in certain places and cases, for the reason that the WWs are easy to construct control, and maintain, moreover, the WWs are aesthetically favourable [31].

2.4.3.2 Comparison of Impulse turbine and Reaction turbine

Table 3 Difference between impulse turbine [12-15, 18, 20, 25-27, 30, 36-43]

Reaction Turbine	**Impulse Turbine**
The available energy of the water is not converted from one form to another.	The entire available energy of the water is first converted into kinetic energy.
The water is guided by the glide blades to flow over the moving vane.	The water flows through the nozzles and imping’s on the buckets, which are fixed to the outer periphery of the wheel.
The water glides over the moving vanes with potential energy.	The water imping’s on the buckets with kinetic energy.
The pressure of the flowing water is reduced after gliding over the vane.	The pressure of the flowing water remains unchanged and is equal to the atmospheric pressure.
It is essential that the wheel should always run full and kept full of water.	It is not essential that the wheel should run full.
It is not possible to regulate the flow without loss.	It is possible to regulate the flow without loss.
Reaction Turbine has relatively less efficiency.	Impulse turbine has more hydraulic efficiency.
Reaction turbine operates at low and medium heads.	Impulse turbine operates at high water heads.
Examples of Reaction Turbine are Francis, Kaplan, and propeller turbine.	Examples of Impulse turbine is Pelton, Turgo turbine.

2.4.3.3 Selection of Impulse Turbine

Impulse turbine was chosen after the comparison between of the reaction turbine. In the categories of impulse turbine, turgo turbine and pelton turbine is normally fund and used in PHP generator system.

Figure 3.13 shows an example of pelton turbine designed and implemented in the PHP generator system. Figure 3.14 shows an example of the turgo turbine designed and implemented into the HP system.

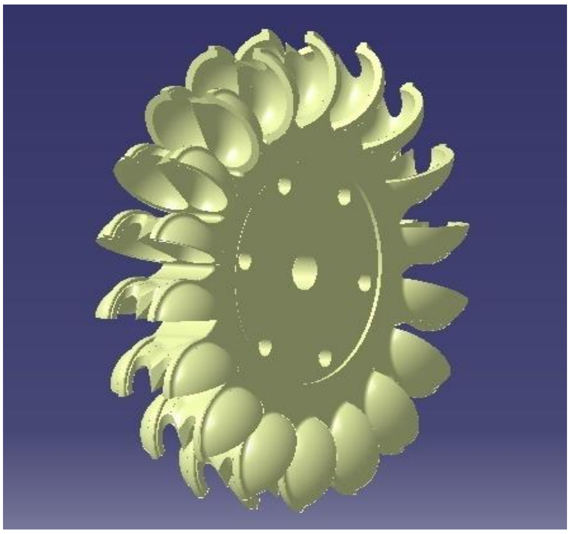


Figure 2.4 Design of Pelton Turbine [16]

Figure 2.5 Design of Turgo Turbine [20]

2.4.3.4 Selection of turbines

The selection of turbines is depending on many criteria, such as (a) Net water head (b) Variation of water flow discharge through the turbine (c) Speed of generator, , the ratio of the rotational speed and turbine must be less than 3:1 [32]. (d) Cavitation problems e.g. the water quality in penstock (e) Cost of turbines. The net head is the most crucial criterion should be considered in turbine selection. The following turbine selection chart (Figs. 2.2 and 2.3) are well known and are suitable for larger turbines.

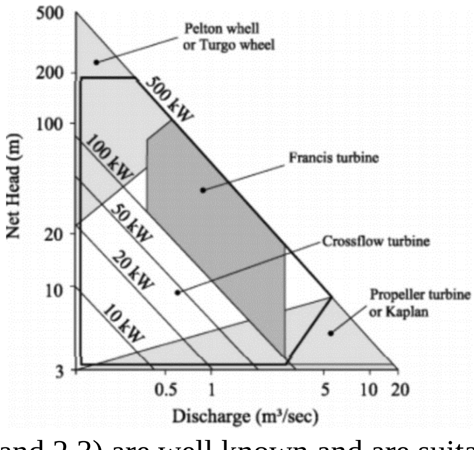


Figure 2.6 The selection ranges of small/micro-HP turbines with net heads and water flow rates variation [33,34]

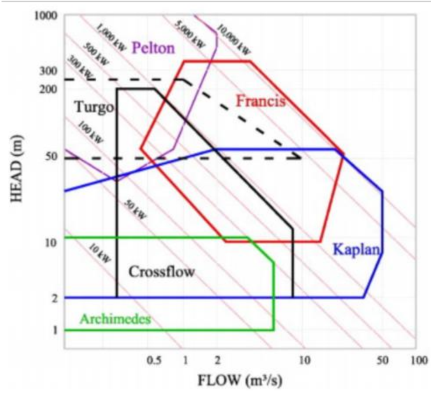


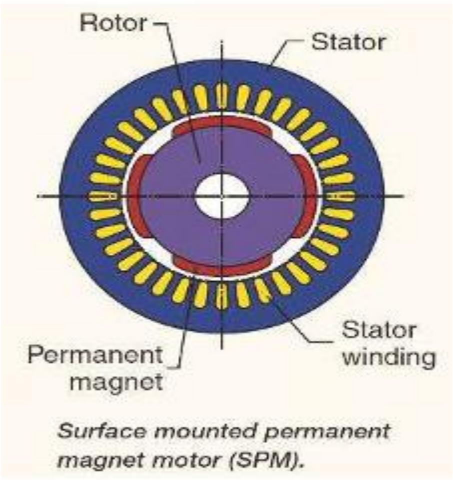
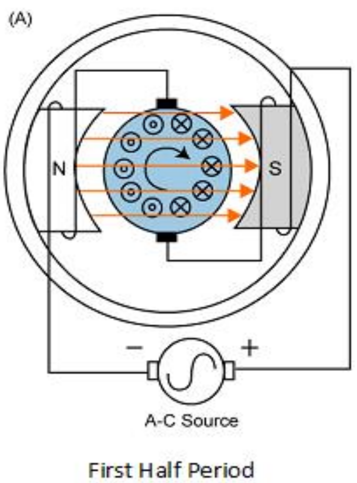
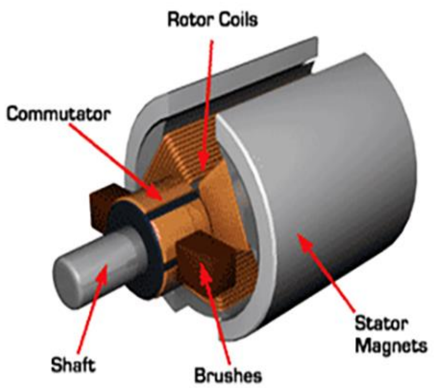
Figure 2.7 A typical water turbine application range diagram [35]

2.4.4 Generator

Generator is an in dispensable component of HP and PHP, the function of the generator used in HP and PHP is to generate electricity. For a small-scale generation, the induction generator converts potential energy to kinetic energy then electric energy. The rotor spins above synchronous speed and develops a counter-torque that opposes this over-speed, same effect as a brake.

In this proposed system, a permanent magnet DC generator is used. One significant advantage of using DC type of PMG is that DC generator is designed to provide high currents at minimum voltage requirement for the charging of battery and operation of direct current loads. Moreover, permanent magnet generator is selected as it is much cheaper and has smaller overall size rather than that of wound field. Other than that, this type of generator is more efficient because no power is wasted to generate the magnetic field [38].

Table 4 Types of electrical machines

Generator type	Characteristics
Synchronous AC machine 	Rotor magnetic field produced by permanent magnets, or (for larger machines) an electromagnet fed via slip rings Output frequency locked to shaft frequency Small PM machines are efficient, quite simple and flexible [19].
Induction AC machine 	Rotor magnetic field induced by stator field (like a transformer) Output frequency differs slightly from shaft frequency Cheap, robust, simple and reliable Some subtleties in getting them to operate as generators Usually less efficient than synchronous machines [20].
DC brushed machine 	Requires slip rings or brushes, which wear out, cause voltage drops and various other problems at high speeds / loadings [20].

2.4.5 Power Estimation

The feasibility of the proposed Pico hydropower system is generally based on the following potential equation of input and output power.

$$P_{in} = H * Q * g \tag{2.20}$$

$$P_{out} = H * Q * g * \eta \tag{2.30}$$

$$Pin = Input\ power\ (Hydropower)$$
$$Pout = Output\ power\ (Generator\ output)$$
$$H = Head\ (meter)$$
$$Q = Water\ flow\ rate\ \left(\frac{liter}{second}\right)$$
$$g = gravity\ \left(9.81\frac{m}{s2}\right)$$
$$\eta = efficiency$$

Head is a measure of the turbine's falling water, the vertical distance from the top of the penstock to the bottom turbine. The water flow rate, on the other hand, is the number of waters flows in a second. Normally, the available water flow is more than necessary as the pico-hydro flows are small. Thus, due to the greater head, the greater power, and the higher turbine rotation speed, it is important to measure the head carefully. The power generated by a hydropower system is essentially converted from one form to another. The first stage of loss is penstock power loss. This is called the friction loss in the pipelines for the proposed pico-hydro system. Before considering the losses in the pipelines, the drop is referred to as the gross head and is called the net head after losses have been subtracted.

For the proposed pico-hydro system, the greatest loss usually occurs when the water pipeline power is converted into rotating, mechanical power by hitting the turbine blades 30% of the total hydropower out of the nozzle. Once the mechanical power is converted to electricity, another 20% to 30% will be lost in the generator. Thus, the thumb rule for estimating the potential output power is usually 50%.

2.4.6 Charging Circuit

For energy storage purpose, the generator output is connected to the charging circuits. Charging circuit is needed to charge the battery at the same time distribute power output from the generator to the loads [39].

2.4.7 Battery

To maintain a sustainable energy provided, a battery has to implemented into the PHP system. The rechargeable battery is a group of one or more secondary cells (also known as a storage battery). Rechargeable batteries use electrically reversible electrochemical reactions. Rechargeable batteries originated in many dissimilar sizes and use various chemicals combinations. A charge controller circuit was required to control the rechargeable battery charge and discharge process.

2.4.8 Electrical Loads

Loads can be divided into lots of categories, it could be high loads, medium loads, and small loads. Basically, the loads in house is small loads, such as lamp, fan, phone charger, and etc.

2.5 Conclusion

In the nutshell, the literature review and previous study, research of renewable energy should be continuing and expand. Numerous aspects must be the sum in before connecting the Pico hydropower generation system in the residential area specifically for the house. Water pressure from a particular source should be measured in order to guess output power. It also benefits to choose the correct generator, turbine, and maximum load that can be supported by the whole system.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology is research about the way we design, conduct, analyse, report, and interpret research studies. In this chapter, we will explain on the procedure of the pico-hydropower generator system. The methods used in this chapter are aimed to achieve the objectives of the project which will give satisfying results on the performance of the pico-hydropower generator system. The overall project implementation and completion is expected for 28 weeks. According to the course timeline which is divided for Senior Design Project I and II, each phase for the realization of project is taken into consideration.

3.1.1 First Phase

For the first phase occurring in the initial 14 weeks, the inception and conceptual stage takes place. Within this phase, several researches will be reviewed which deemed appropriate for the project as well as identifying the problem statement for current objectives. Afterwards, measurement and data gathering will be starting at the control site and this may include flow rate (m3 /s) and also velocity of water (m/s). From hand sketches to using Solidworks software, the overall design of the components for the system are modelled in 3D.

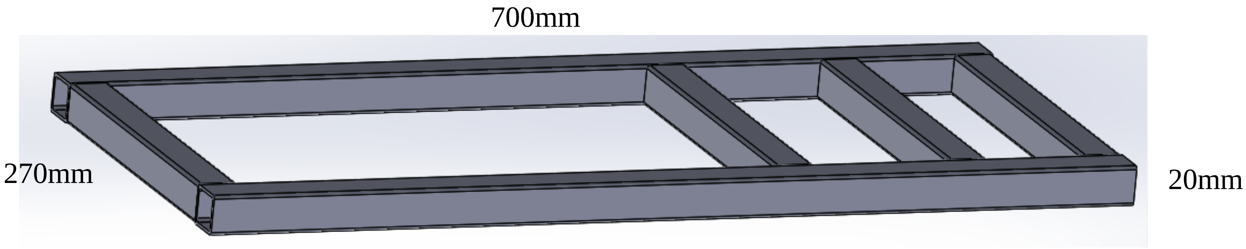


Figure 3.1 Bracket of picohydro system drawing in solidworks

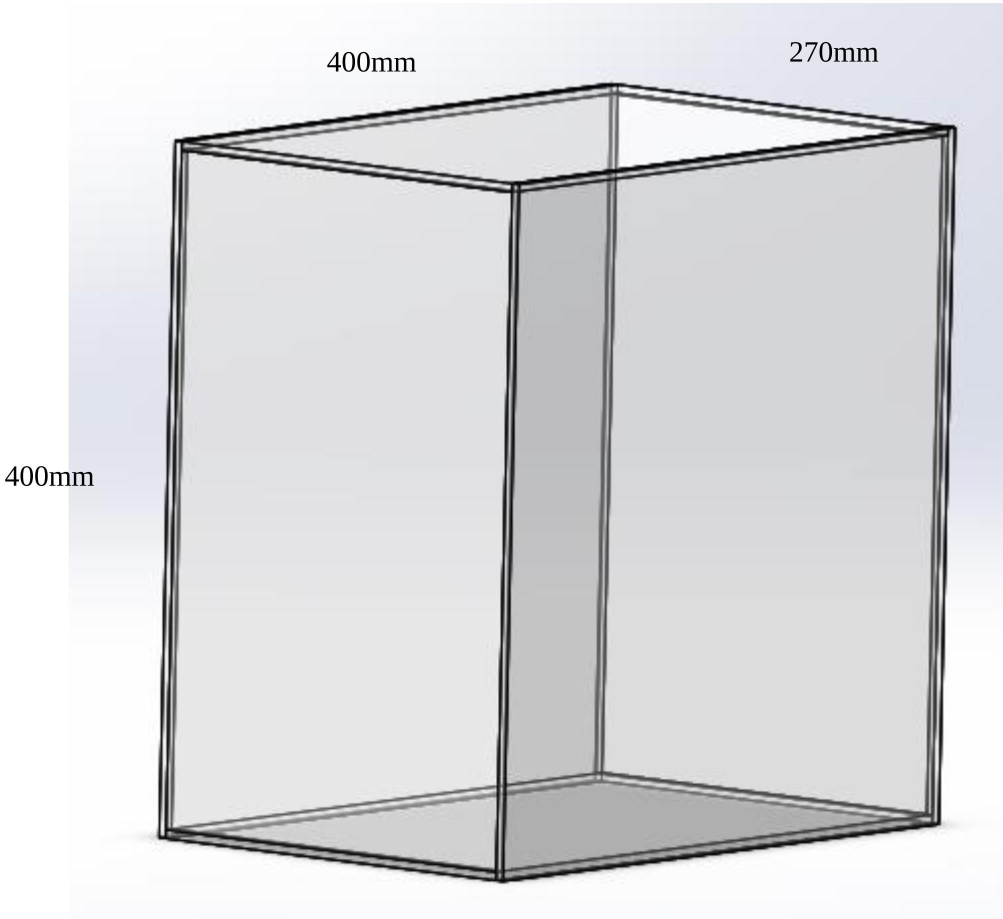


Figure 3.2 Cover for turbine design in solidworks

3.1.2 Second Phase

The second phase of the project commences at the final 14 weeks of the course timeline. This phase involves the implementation and analyse stage. The fabrication will involves manual labour in terms of metalworking processes such as welding, bending and lathing. Flsun cube 3D printer used to fabricate the nozzle and turbine. After fabrication, site testing will proceed with the produced system model. Several measurements will be taken on site such as power output from the turbine (W), torque produced (rpm) as well as velocity of water flow and jet flow (m/s) which are important to study the effect of this parameters on turbine performance. Afterwards, a feasibility study will be done to assess the impact of this project towards the water treatment facilities.

3.2 Flow Chart of Methodology

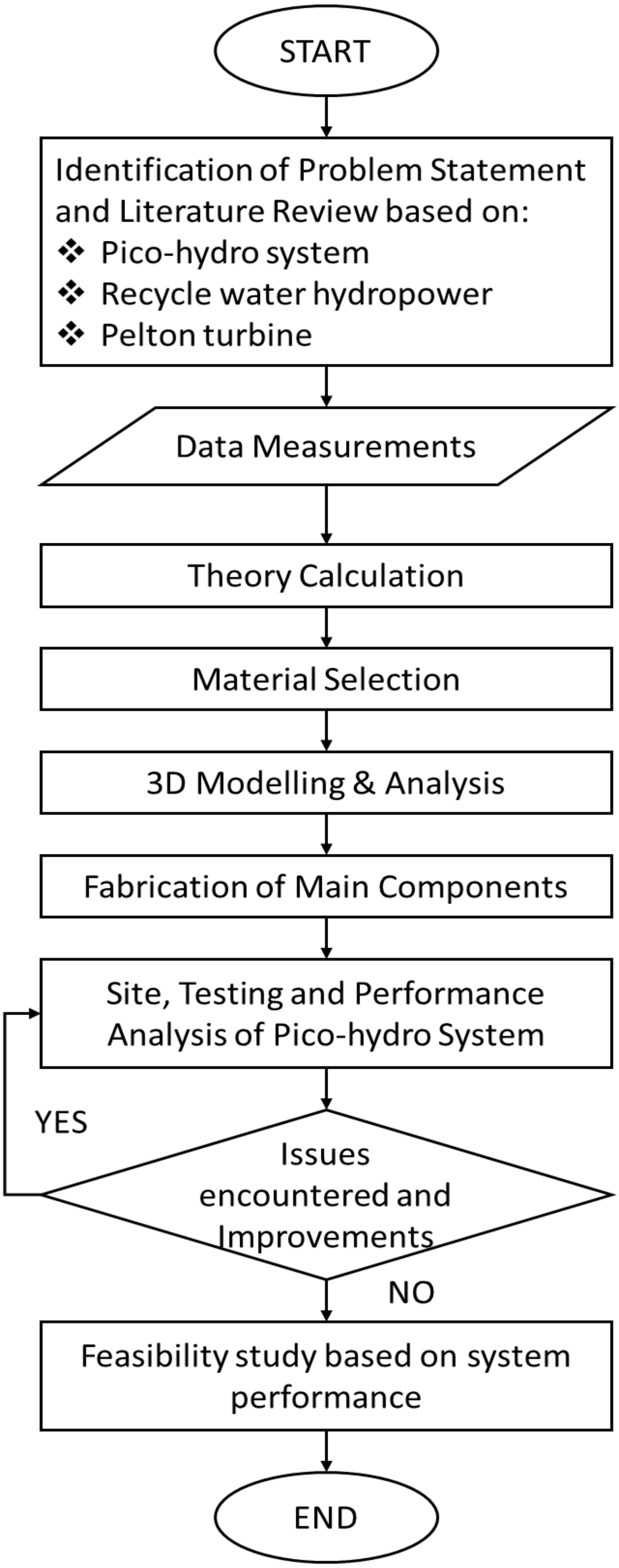


Figure 3.3 Project Flowchart

3.3 General Flowchart

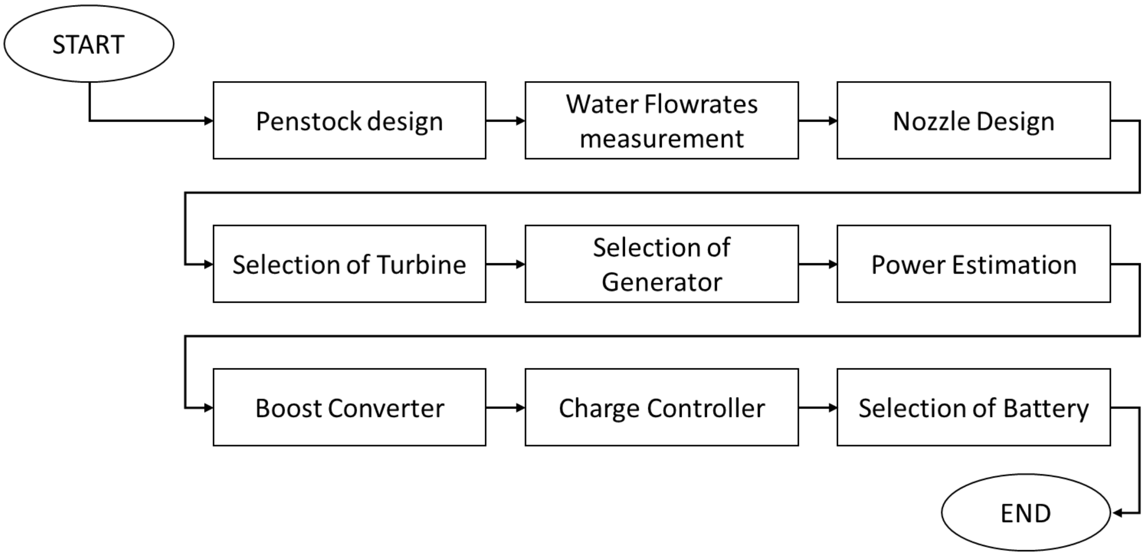


Figure 3.4 Pico Hydropower generator system planning

3.3.1 Penstock Design

Piping system is used to carry water to a turbine. The pipe used in the design must be planned with the capability to produce high pressure of water to rotate the turbine at the highest speed. Due to the resistance of the pipe material and the fittings in which type of bend used, necessarily friction losses will occur. The pipe length and diameter of pipe need to consider in order to handle the amount of water flow. By selecting appropriately all the parameters mentioned above, friction losses can be reduced. In figure 3.2 below shows how to properly design pipe with taking all consideration to reduce friction losses in the pipeline. The Darcy formula or the Darcy-Weisbach equation is now acknowledged as the most exact formula for loss of pipe friction, and although it is tougher to calculate and use than another formula for loss of friction, it has now become the typical equation for engineers with the introduction of computers. Weisbach first proposed the relationship to calculate friction loss in a pipe as the Darcy-Weisbach equation or the Darcy-Weisbach formula [40].

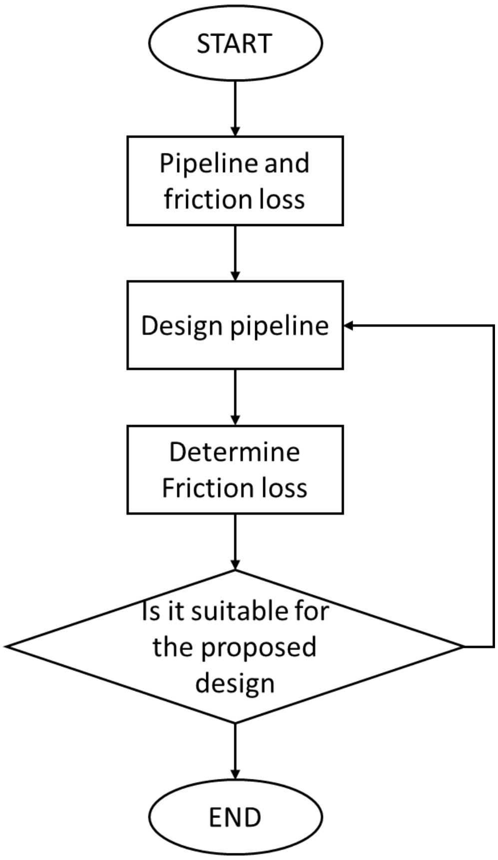
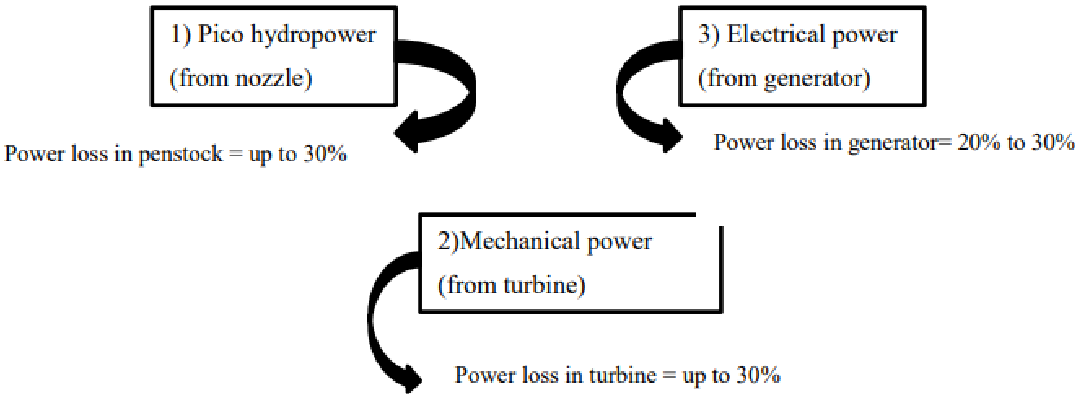


Figure 3.5 Penstock design planning



Generally, the power generated by a hydropower system is changed from one form to another, some are lost at each phase. The figure 3.3 shows that the first phase of loss is penstock power loss. This refers to the friction loss in the penstock for the planned Pico hydropower system. Before taking into justification the losses in the penstock, the drop is referred to as the gross head and is named the net head after losses have been deducted [41].

3.3.2 Water Flowrates Measurement

The simplest of flow measurement for small streams is the bucket method [42]. Therefore, this method has been used due to the capacity of the proposed hydropower system is significantly small. Moreover, this method is considerably practical due to the proposed hydropower system is very uncommon compared to other system in its category in which the source of energy is from the consuming water distributed to houses by the Water Utility Company. Throughout this method, the flow rate of the distributed water is diverted into a bucket or barrel and the time it takes for the container to fill is recorded. The volume of the container is known and the flow rate is simply obtained by dividing this volume by the filling time. For example, the flow rate of water that filled 5 litres bucket within one minute is 5 litres per minute or 0.0833 L/s. This is repeated several times to give more consistent and accurate measurement.

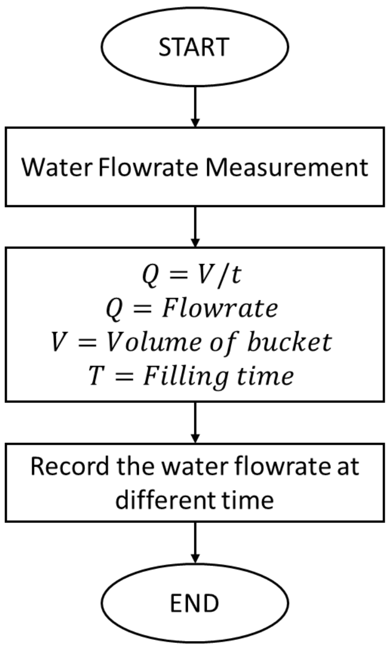


Figure 3.6 Water flowrate measurement method

3.3.3 Nozzle Design

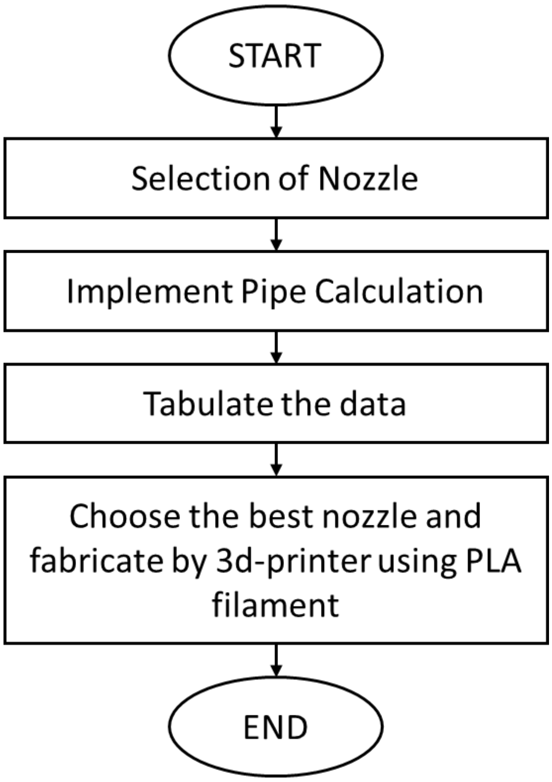


Figure 3.7 Nozzle Design planning

3.3.3.1 Selection of Nozzle

Nozzle are mechanical devices designed to control the direction or characteristics of a fluid flow and specially to enhance the velocity of fluid as it passes through [44].

Nozzle is the important part in this experiment. The changing of the nozzle will affect the performance and efficiency of the PHP system. The blade width to nozzle diameter ratio (w/d) has an important influence on the way water flows over a curved surface [43]. As this ratio decreases there is increasing turbulence and re-circulation, which disrupts the flow. There are many types of nozzle was designed by engineer in the world but it consists of many fields, a suitable nozzle implemented into the PHP system is important and it can increase the efficiency of the PHP system. Figure 3.6 shows that the type of nozzle normally used in the Malaysia market.

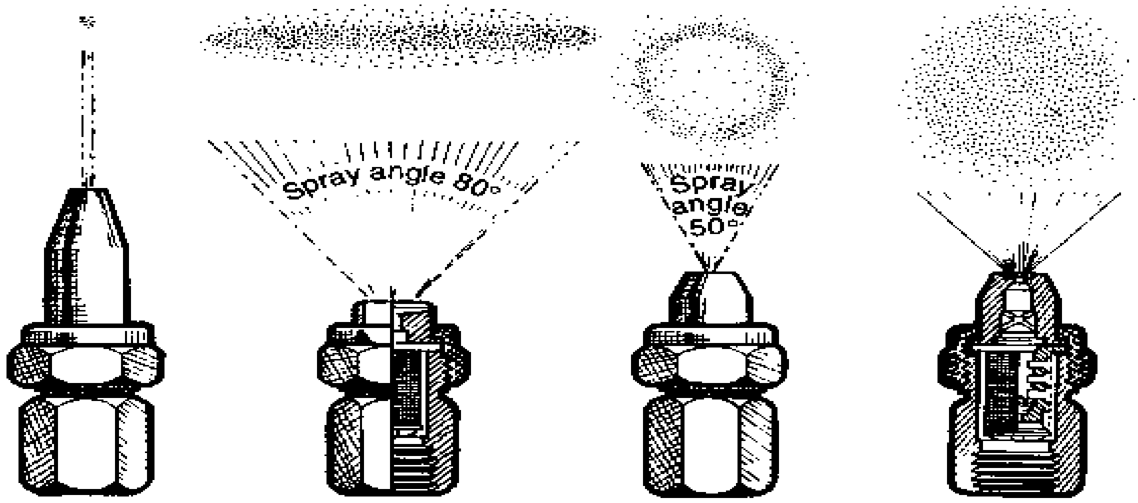


Figure 3.8 Type of nozzle in the market

3.3.3.2 Implement Pipe calculation

In this experiment two type nozzle was designed by implemented the design and calculation of the pipe, which is gradually reduction pipe and sudden reduction pipe. Figure 3.7 and 3.8 shows that the design of the nozzle by implement the idea of pipe system.

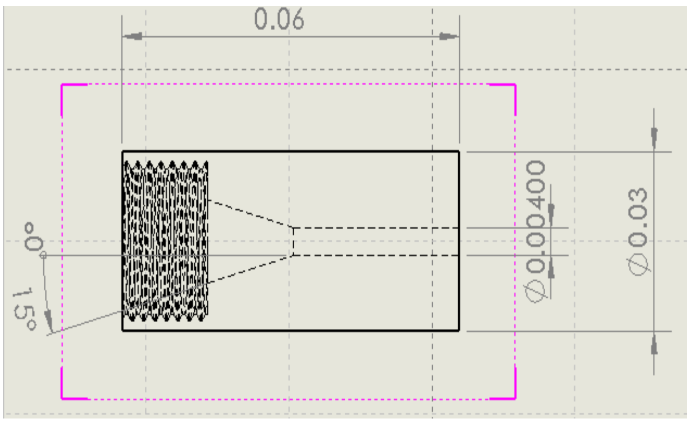


Figure 3.9 Gradually reduction pipe design in solidworks

To calculate the velocity, pressure, head loss of water in the nozzle designed a coefficient of pipe is needed as a guideline for the design. Figure 3.9 and 3.10 shows that the coefficient graph of gradually reduction pipe and sudden reduction pipe. Both of this coefficient is a national standard.

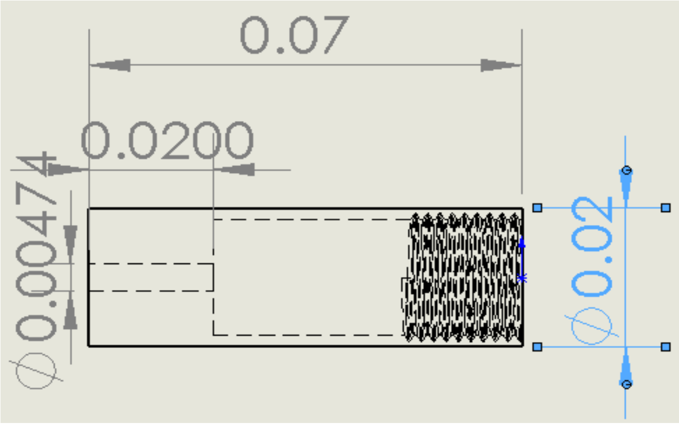


Figure 3.10 Sudden reduction pipe design in solidworks

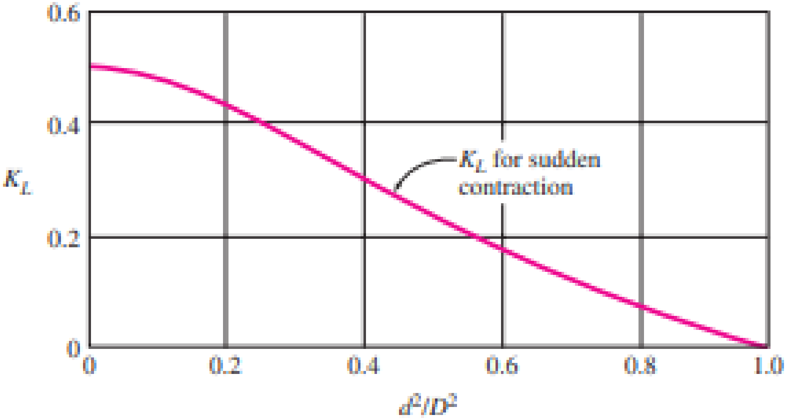


Figure 3.11 Coefficient graph of sudden reduction pipe [44]

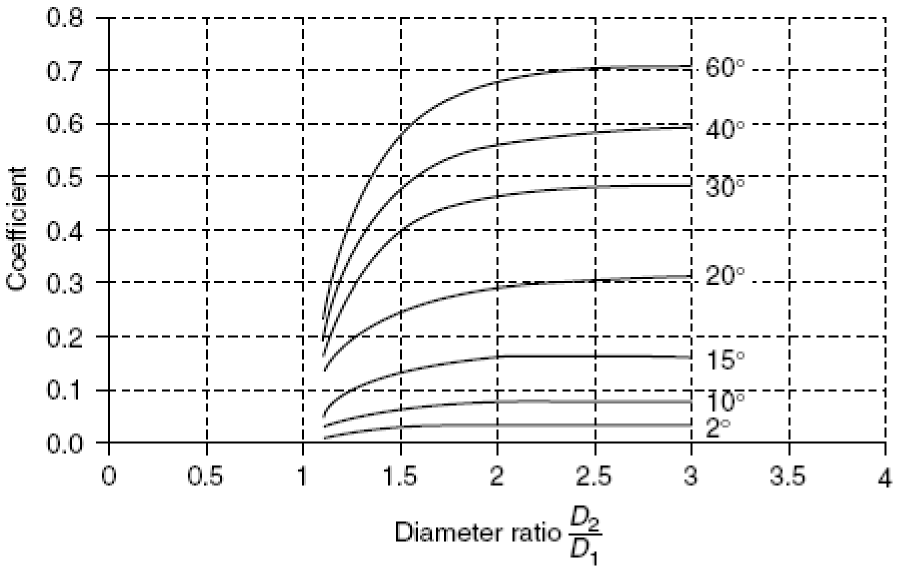


Figure 3.12 Coefficient graph of gradually reduction pipe [44]

Maximum Water flow rate calculation:

$$Q = V/t \tag{3.10}$$

$$Q = Flowrate$$
$$V = Volume\ of\ bucket$$
$$T = Filling\ time$$

$$Q = \left(\frac{1.7L}{24.5s}\right)$$
$$Q = 4.167L/min$$
$$= 250L/hr$$
$$= 6.9444 * 10^{-5}\ m^3/s$$

Maximum water velocity in the pipe before nozzle:

$$Velocity\ of\ water\ (V) = \frac{flowrate\ (Q)}{area\ (A)} \tag{3.11}$$

$$= \frac{6.9444 * 10^{-5}\ m^3/s}{1.257 * 10^{-5}\ m^2}$$

$$= 5.525 m/s$$

Water flowrate will change by the pressure of water, but the it will not change by the area of pipe.

$$Q_1 = Q_2 \quad (3.12)$$

$$\frac{V_1}{t_1} = \frac{V_2}{t_2} \quad (3.13)$$

$$A_1 V_1 = A_2 V_2 \quad (3.14)$$

Sudden reduction nozzle design:

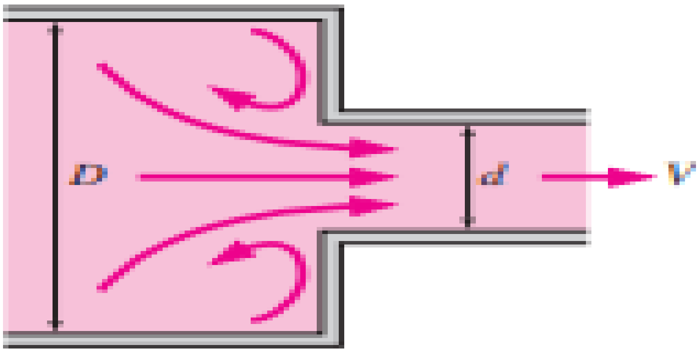


Figure 3.13 Sudden reduction nozzle parameters

$$Diameter\ ratio = \frac{d^2}{D^2} \quad (3.15)$$

The diameter of water inlet = 12mm

Table 5 Diameter, Radius, Area, and Velocity for sudden reduction nozzle based on parameter in Fig 3.9

units	ratio (d^2/D^2)				
	0.1	0.2	0.4	0.6	0.8
Diameter (d) (mm)	3.795	5.367	7.589	9.295	10.733
Radius (r) (mm)	1.8975	2.6835	3.7945	4.6475	5.3665
Area (A) (mm^2)	11.313	22.626	45.239	67.865	90.487
Area (A) (mm^2)	1.131e-5	2.262e-5	4.523e-5	6.786e-5	9.048e-5
Water Velocity (m/s)	6.14	3.07	1.54	1.02	0.77

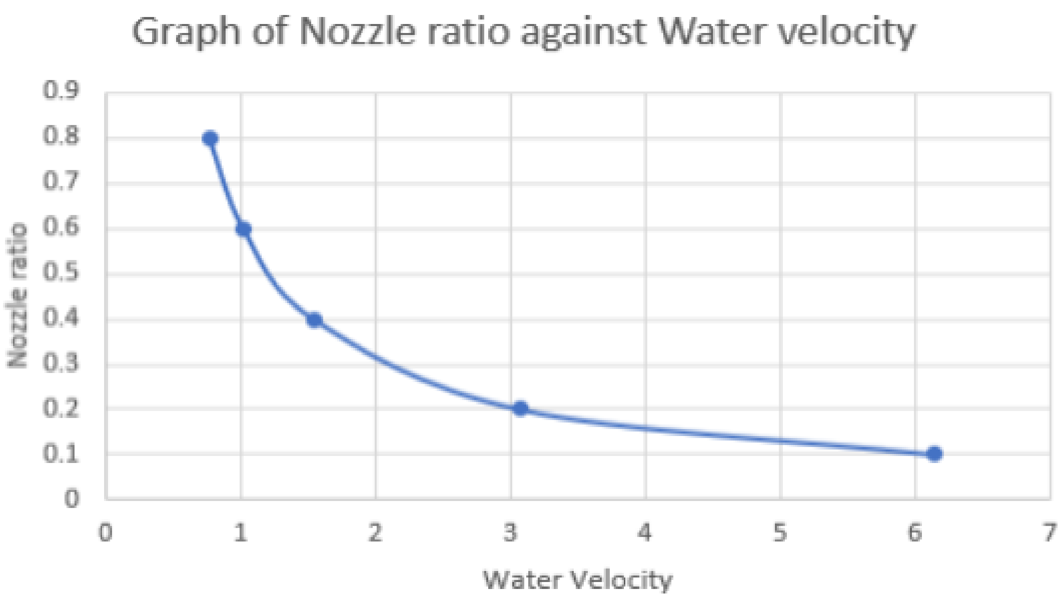


Figure 3.14 Graph of Nozzle ratio against the output water velocity

Based on the equation:

$$A_1V_1 = A_2V_2 \tag{3.16}$$

The output water velocity from the sudden reduction nozzle recorded in table 4. Based on the equation and the output result calculated, the smaller ratio the higher output of the water velocity. From the data in the table 4 and the graph of figure 3.12 shows that the output water velocity is directly proportional to the coefficient graph in Fig 3.9.

Based on the calculation of the sudden reduction nozzle, the gradually reduction nozzle can be estimated have the same situation in the ratio of the nozzle. After added the degree of slope, it can decrease the friction force and decrease the coefficient number as Fig 3.10.

3.3.4 Selection of turbine

Selection of turbine is important and is a must step to be executed in build up every PHP generator system. The reaction turbine is generally completely immersed in water and is enclosed in a casing of pressure. A turbine with hydropower is a device that converts the flowing water energy into mechanical energy. Impulse turbine more suitable to be implement in this project due to the low-head and high-water flow volume. Pelton turbine and Turgo turbine is the choice after comparison between of them.

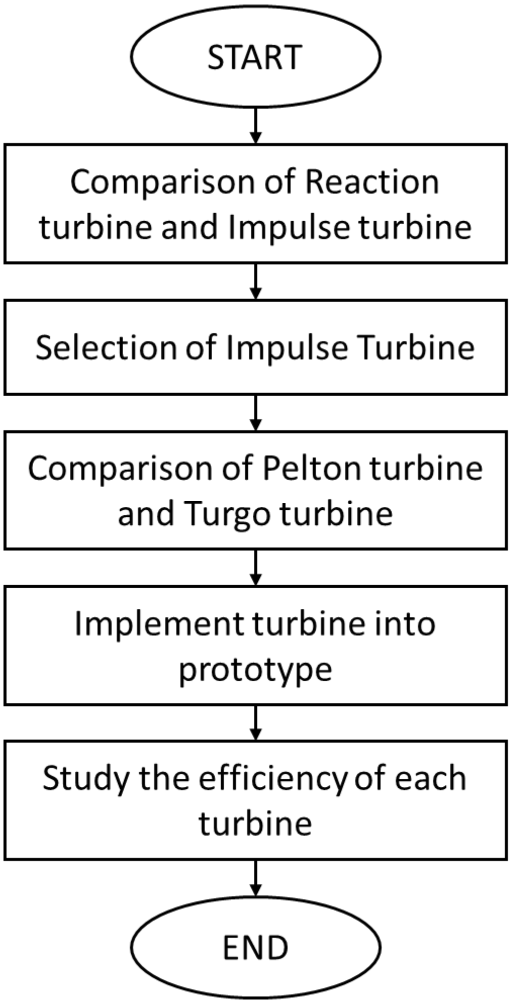


Figure 3.15 Turbine selection planning

3.3.5 Selection of generator

In this project, a brushed DC motor was used as a generator. The electric generate by the brushed DC motor is a DC voltage, DC voltage easier to control and used.

Figure 3.16 PMA motor implemented in prototype as generator

3.3.6 Boost Converter

LM2587s is a stable chip to use in the buck and boost converter. Figure 3.15 shows that the boost converter sells in cytron.

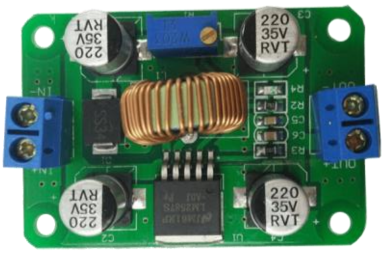


Figure 3.17 Boost converter circuit in PCB board

3.3.7 Charge Controller

Energy cannot be stored and it will only change their form to another energy. The generator output is connected to the charging circuits for energy storage purpose. The battery charger is suitable for 9V to 12V batteries. For charging purpose, the maximum load current is limited to 1.5A. This is based on the maximum load current of the LM317 voltage regulator and the maximum current at continuous duty of the generator. In addition, due to the generating capacity of the pico-hydro system, Ni-Cad battery is preferred.

3.4 Project Activities

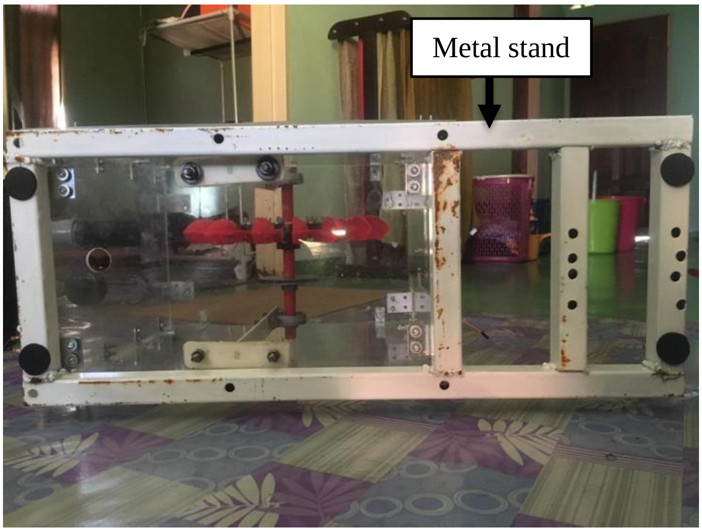


Figure 3.18 Fabrication of stand by metal bar

1. Fabrication of Stand

The stand was modelled based on design done through Solidworks software. Gas MIG welding machine used to weld the metal bar together.

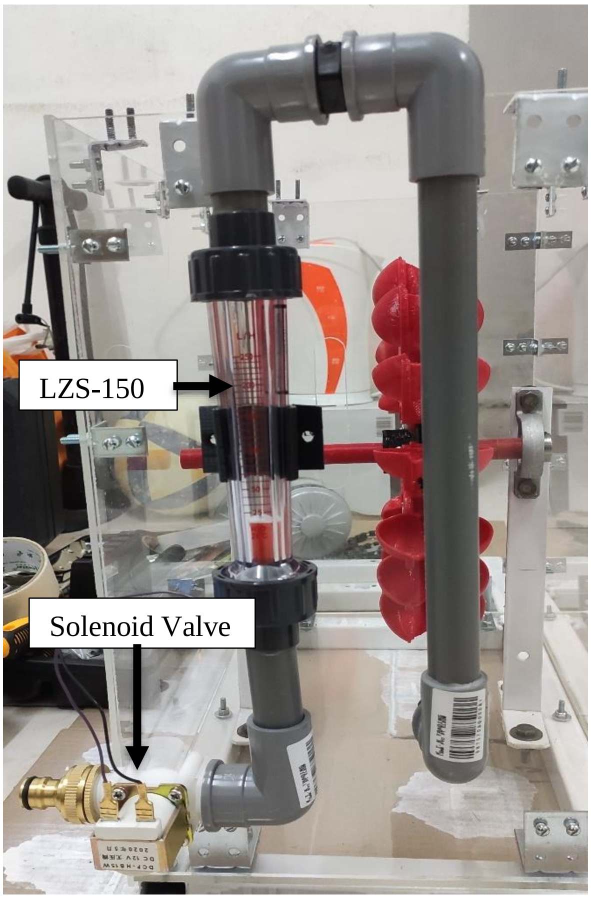


Figure 3.19 Connection of piping system with LZS-150 water flowmeter

2. Piping system Connection

A diameter 15mm PVC pipe used as the piping system in the pico-hydro system. Solenoid valve and LZS-150 flowmeter was connected in the piping system as figure 3.17. The main purpose of choosing 15mm PVC pipe is because the standard size of pipe used in houses of Malaysia is 15mm.

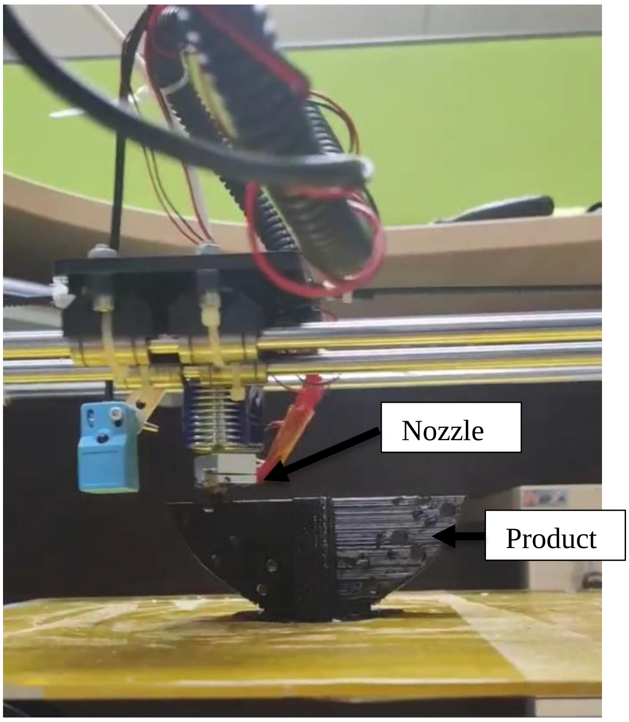


Figure 3.20 Fabrication nozzle and turbine by Flsun Cube 3D-Printer

3. Fabricate nozzle and turbine using 3D-printer

Solidworks used to design the nozzle and turbine and PLA filament as an extruder used to fabricate the nozzle and turbine. Flsun Cube 3D-printer was used to build the prototype of nozzle and turbine because it has a large scale which can print maximum (260x260x350)mm.

3.5 Pico-hydropower generator system design (sketch)

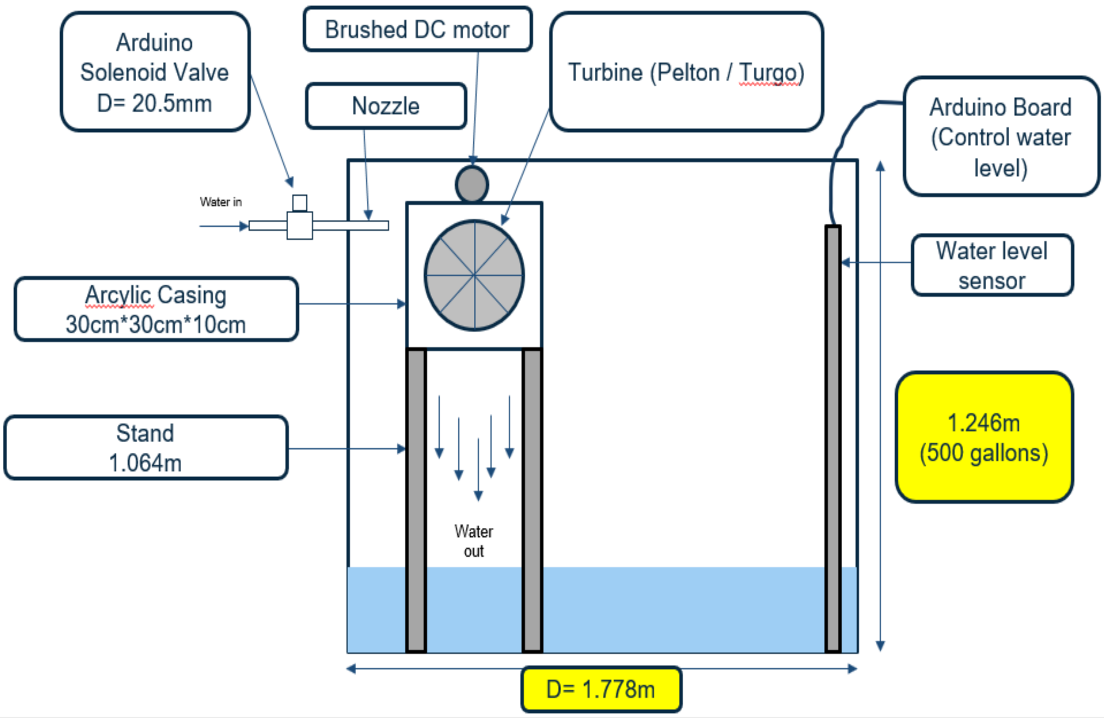


Figure 3.21 Design of the Pico-hydropower generator system in the water tank

3.6 Pico-hydropower generator system

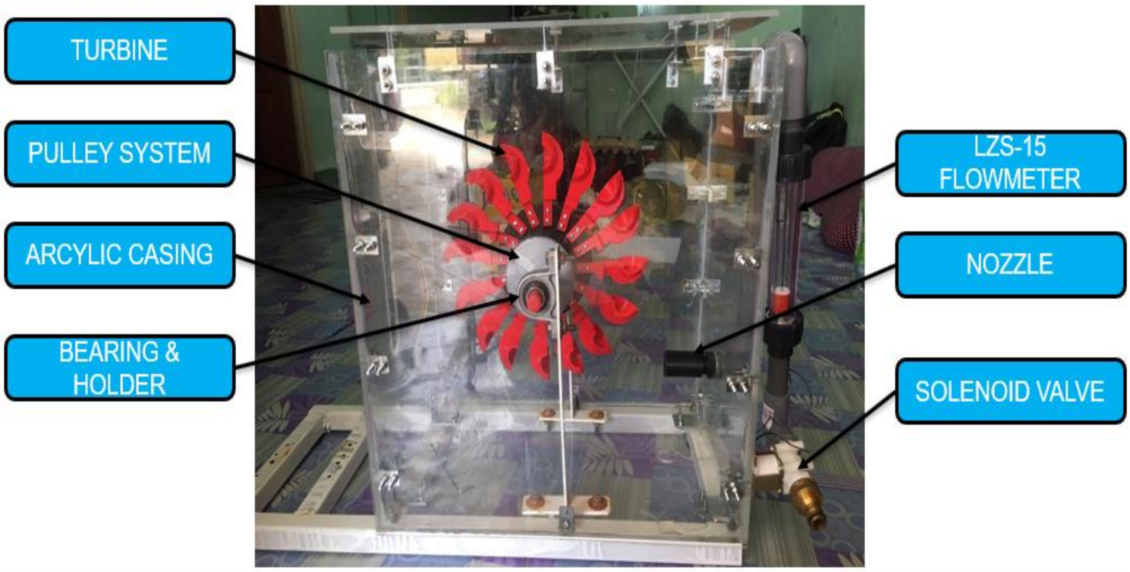


Figure 3.22 Pico-Hydropower Generator system built

3.7 Controller system use Arduino

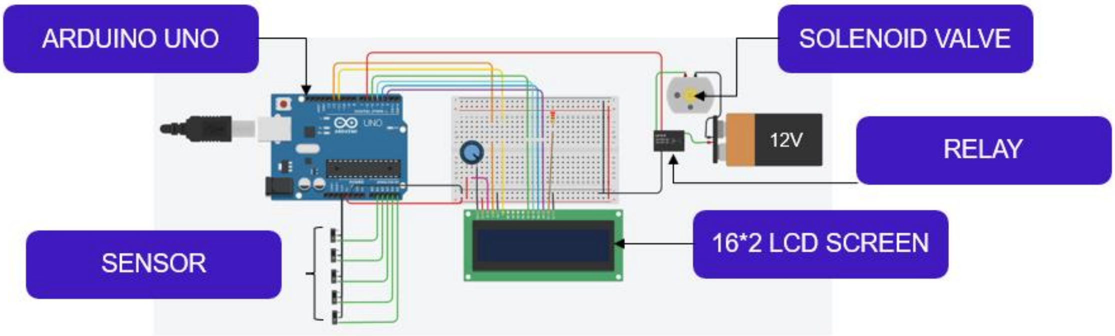


Figure 3.23 Circuit diagram of the controller to monitor the water level and control the water fill into water tank

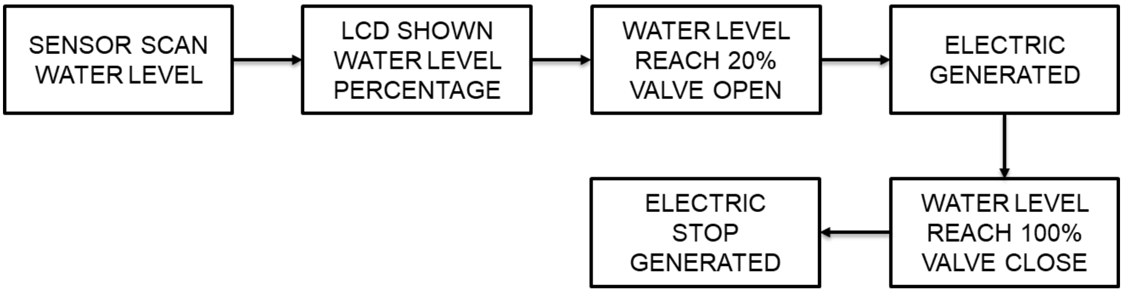


Figure 3.24 Block Diagram of Arduino Controller

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This prototype was implemented to the water tank and it run with the pipe water for energy measurement purposes. Water from water inlet is driven into the PHP system by using PVC pipe. This development has done with many changes until it gets close to the required RPM and power output. All this change is distributed in the following three experiments which are the experiments consists of sudden reduction nozzle, gradually reduction nozzle and flowrate of water.

4.1.1 Pico hydropower development

Figure 4.1 Hardware prototype development (Front view)

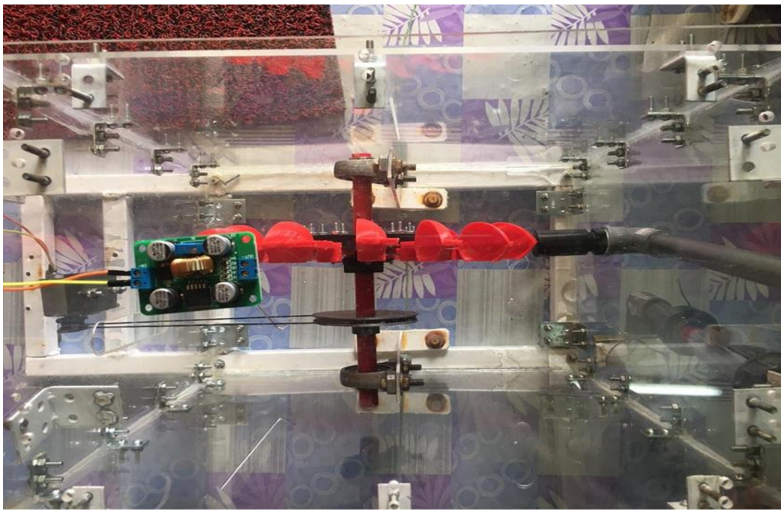


Figure 4.2 Hardware prototype development (Top view)

Figure 4.1 and 4.2 show that the prototype of the PHP developed. While fabricating the prototype, there are lots of condition that need to be considered. Acrylic with 5mm thick used to build the 40cm*40cm*25cm rectangular casing of the PHP. This size of casing enough to implement the turbine designed and fabricated by 3d-printer. Turbine placed in the middle of the box and is attached to bearing where the bearing is the most important kit because bearing will create a turbine to rotate faster compared to others. The generator is placed parallel to the wheel of the turbine. When the turbine is rotating, the turbine wheel creates a ratio of the speed was 1: 10-speed ratio due to the smaller wheel at the generator. By using this speed ratio, the speed of the generator rotates faster. To measure the RPM (rotation per minute) of the turbine, the tachometer is used to detect the rotation or speed. The tachometer works like any other meter that measures the rotation. Multimeter used to measure all the parameter that we want to observes which are voltage, current and power output.

4.2 Experimental result

4.2.1 Experiment 1: Gradually reduction pipe test with 8 blades Pelton turbine

The following table below shows the gradually increasing in the speed of the turbine with the different α angle of nozzle. All parameters are proportional to the turbine speed. The increasing of a turbine will increase the output power. From the table 7 and figure 4.3 shows that the maximum turbine speed is the 15° nozzle at flowrate 250L/hr.

Table 6 Gradually reduction pipe at ratio 0.2

Flowrate (L/hr)	Turbine speed (rpm)		
	15 degree	**30 degree**	**60 degree**
100	24	10	8
150	70.2	30.2	29.5
200	119.8	50.9	35.7
250	277.8	107.5	70.5

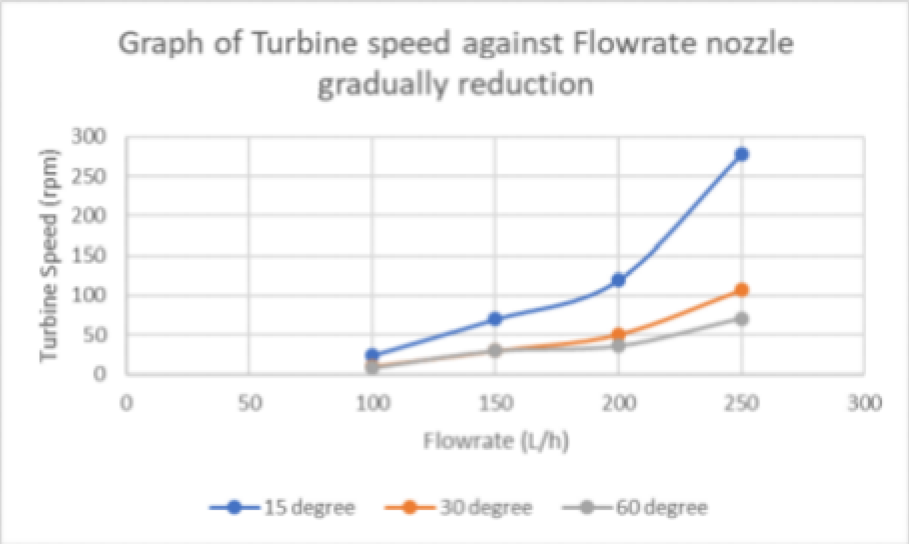


Figure 4.3 Graph of turbine speed vs water flowrate

Based on the graph in figure 4.3, the smaller the degree of nozzle, the higher the pressure of water generated. The pressure of water high it can rotate the speed of the turbine.

Table 7 Measured Motor speed, Voltage output, and Current

Flowrate (L/hr)	**Turbine speed (rpm)**	**Motor speed (rpm)**	**Vout**	**Current (mA)**	**Power (W)**
100	24	125.4	0.89	1.1	0.979
150	70.2	301.9	1.19	9.4	11.19
200	119.8	616.5	3.21	54.9	176.23
250	277.8	1432.1	5.89	90	530.1

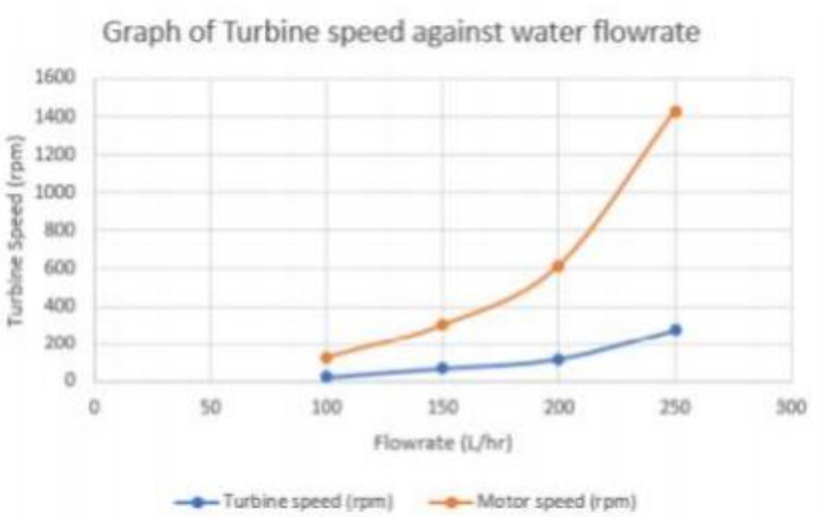


Figure 4.4 Graph of turbine speed and motor speed

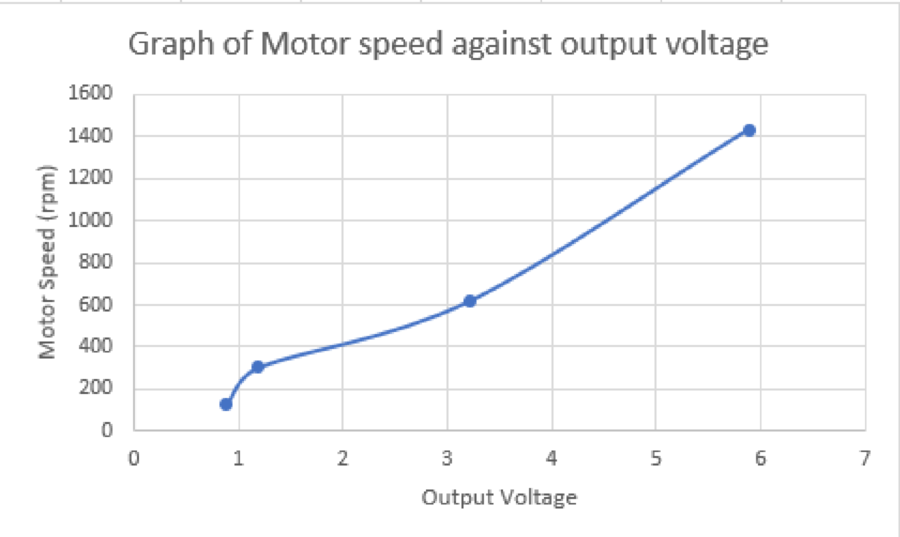


Figure 4.5 Graph of output voltage (V) generated by generator

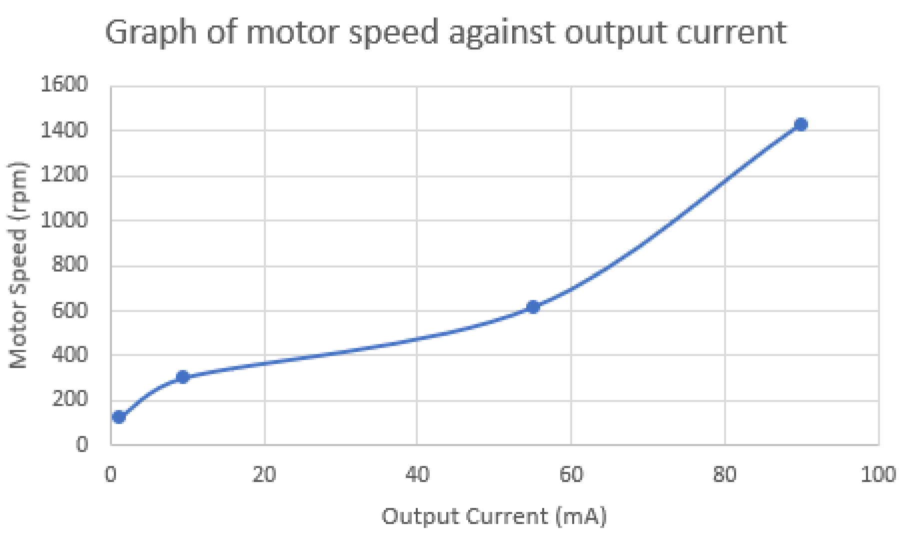


Figure 4.6 Graph of current generated by generator

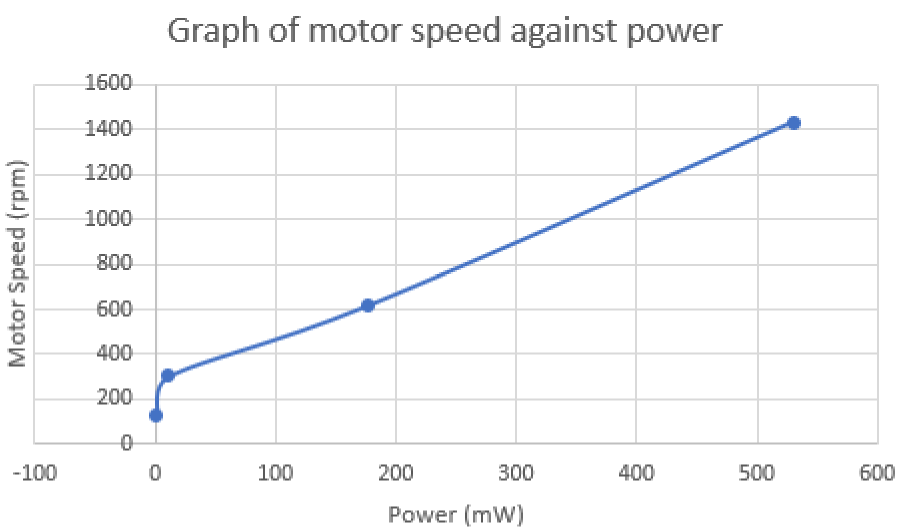


Figure 4.7 Graph of power generated

Table 8 shows the recorded data of the gradually reduction pipe I ratio of 0.2 based on the turbine speed, motor speed, output voltage, output current and calculated power. From the graph in figure 4.4, 4.5, 4.6, and 4.7, we can know that the output is directly proportional to the flowrate of water. Based on this we can said that, the higher the water flowrate, the larger the power generated.

4.2.2 Experiment 2: Sudden reduction nozzle test with 8 blades Pelton turbine

Table 9 shows the recorded reading of the turbine speed at the sudden reduction nozzle ratio at 0.1, 0.25, 0.5, and 0.7 by changing the flowrate.

Table 8 Sudden reduction nozzle

Flowrate (L/hr)	Turbine speed (rpm)			
	ratio 0.1	ratio 0.25	ratio 0.5	ratio 0.7
100	6.5	17.5	9.3	9
150	15.3	48.4	28.4	24.3
200	15.4	80.5	74.9	71.5
250	15.3	145.7	108.7	72.5

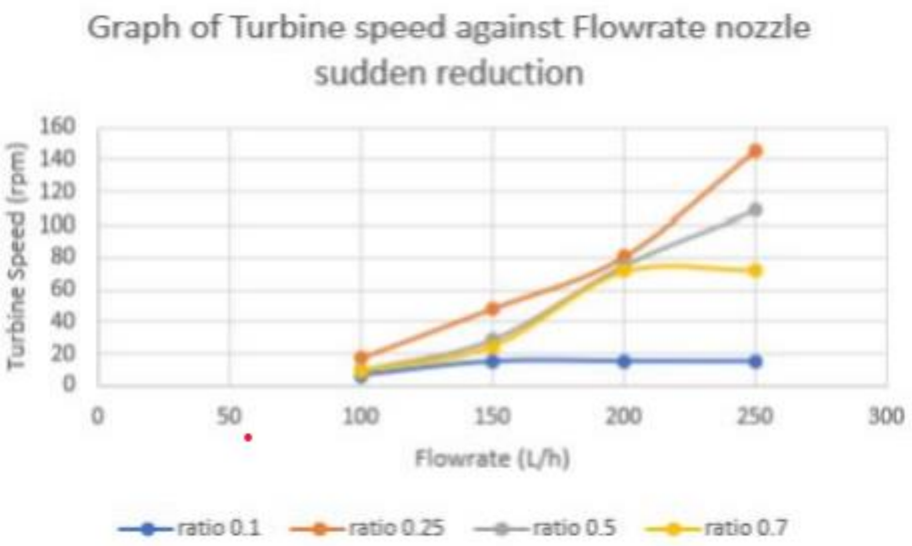


Figure 4.8 Turbine speed changed at different flowrate for the sudden reduction nozzle ratio 0.1, 0.25, 0.5, and 0.7

From the graph in figure 4.8 shows the sudden reduction nozzle with the ratio of 0.25 had the best water pressure output due to the turbine speed is the highest. On the other hand, the nozzle with the ratio of 0.1 don't have the best performance after the flowrate of water reach 150L/hr is due to the maximum water flowrate is reached and the pressure of water cannot increase.

Table 9 Measured Turbine speed, Motor speed, output voltage, output current and power for sudden reduction pipe ratio 0.25

Flowrate (L/hr)	**Turbine speed (rpm)**	**Motor speed (rpm)**	**Vout**	**Current (mA)**	**Power (mW)**
100	17.5	70.2	0.45	0.56	0.252
150	48.4	180.8	0.61	4.7	2.867
200	80.5	391.5	1.7	28.5	48.45
250	145.7	852.3	3.1	46.7	144.77

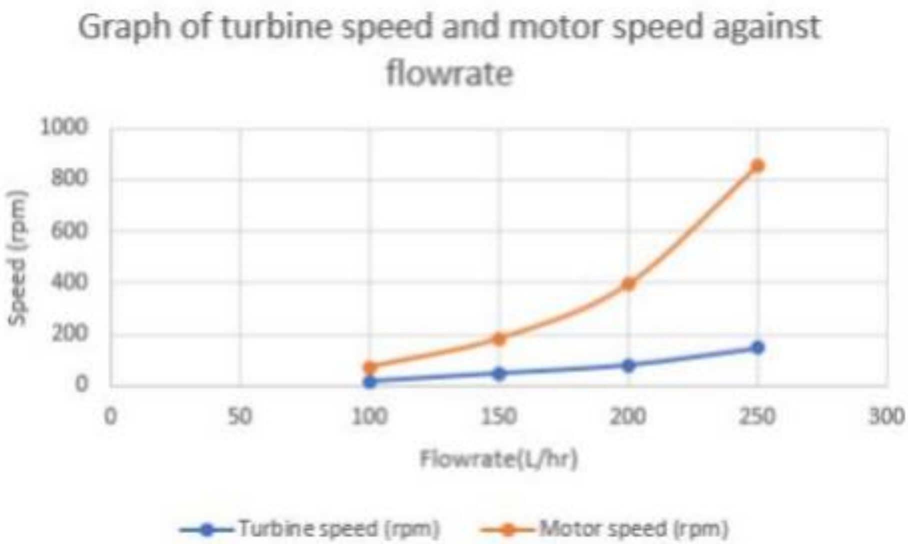


Figure 4.9 Graph of the turbine speed and motor speed in different water flowrate

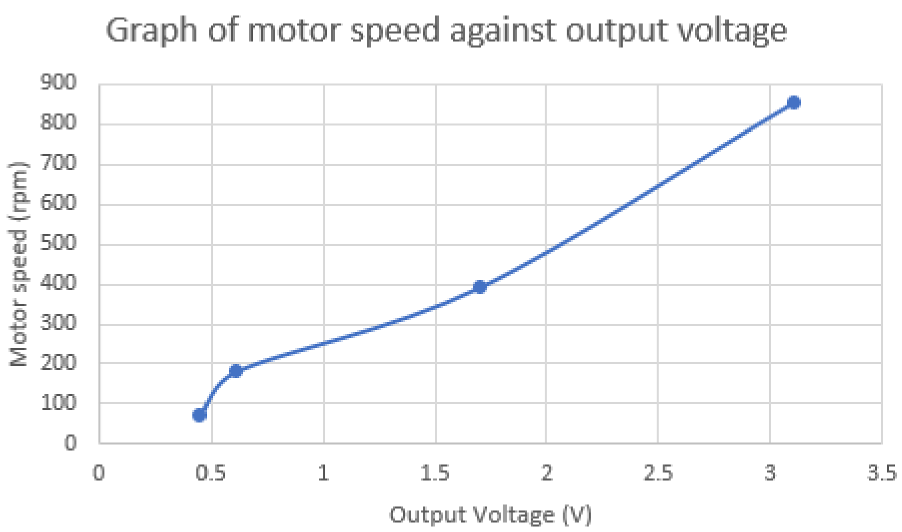


Figure 4.10 Graph of the voltage generated by the generator

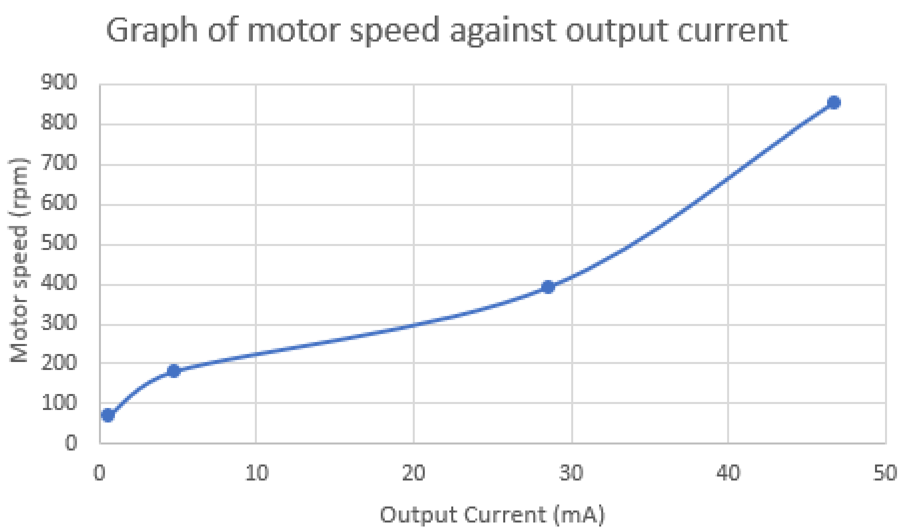


Figure 4.11 Graph of the output current generated by generator

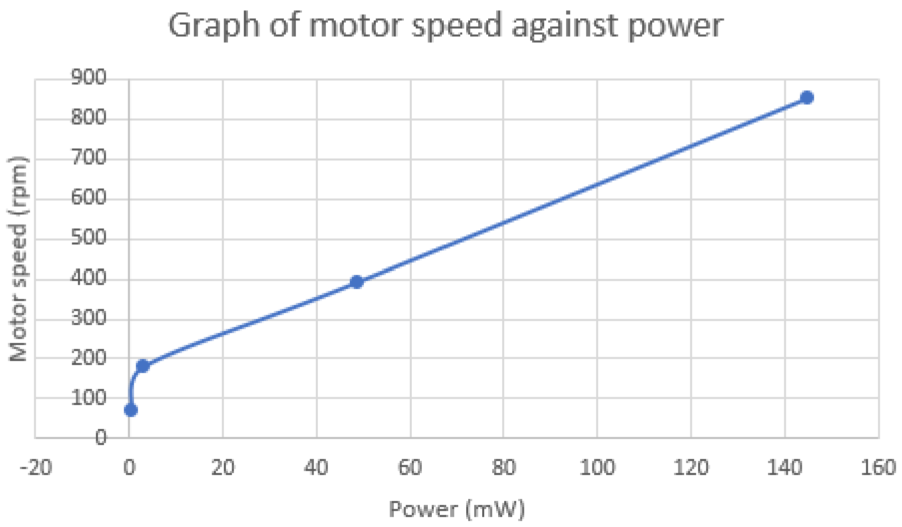


Figure 4.12 Graph of output power generated by generator

Table 10 recorded the measurement of turbine speed, motor speed, output voltage, output current, and power was calculated by using the formula of P=IV. Based on the graph, we can know that the output power is directly proportional to the water flowrate for the constant ratio 0.25 sudden reduction nozzle. At the same time, we can compare the performance of the sudden reduction nozzle and gradually reduction nozzle, the performance of the gradually reduction nozzle is better than the performance of sudden reduction nozzle.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In this chapter, the summary based on the findings in this project will be discussed. As referred to the first objective, to design a movable, easily install and low costs Pico-Hydropower Generator system for house water tank to supply power for charging purpose.

In the nutshell, developing of PHP is various and customised, it could be designed for any situation, condition and dimension. In this project, a gradually reduction nozzle with 15° slope and ratio at 0.25 had a best performance which can generate a 277.8rpm at turbine, after going through a pulley system, can reach 1432.1rpm at the generator. The output voltage generated by generator can reach around 5.89V, 90mA and 530.1mW. Also, at the end of the day, the value of the responding parameters will always be depending on the value of water flow rates. In this project the turbine used is 8 blades pelton turbine and the maximum water flowrate can reach 250L/hr. The power generated by the brushed DC motor is less than the expectation due to the external friction force of the rough surface of turbine fabricated by the PLA filament used 3d-printer. Beside that, the nozzle designed and fabricated by PLA filament used 3d-printer had a rough surface too. The rough surface can be going smooth sanding by sand paper and the rough surface increase the internal friction force of the water when water strike out. The installation of pulley system can increase the rotation of turbine to the generator, and the pulley system used the gear ratio of 1:10. Where, when larger pulley rotates once, another pulley at the generator rotates 10 times faster. So, it creates more speed rather than connected directly the wheel of the generator to the shaft.

When on going the testing step, there are some problems faced the problem was solved. The design part for the nozzle for hydropower is lack in the market and it mostly used in large scale of hydropower but not PHP. When manufacture the prototype the generator had changed once due to the shaft of the generator is harder to turn than expectation. Other than that, is a difficulty in software. To compute the basic thing of a Pico hydropower such as the head, power, and flow, MATLAB software can be used but the difficult part is to create programming that can choose what type of turbines can be used based on the parameters given. The data on each turbine continuously overlay with each other, then the best turbine can be used must be decided manually and based on literature review.

5.2 Recommendations

Recommendations are suggested to improve the research quality in future are listed as follows:

i. PLA+ and ABS material can used to fabricate the turbine and nozzle, because the price is cheaper than PLA filament and weight is lighter.

ii. Using ANSYS features to simulate the turbine performance according to control site parameters.

iii. Choosing a higher specification generator to produce greater capacity of power. Selection of generator can be made by knowing the turbine speed (rpm) through calculations which is relative to power output.

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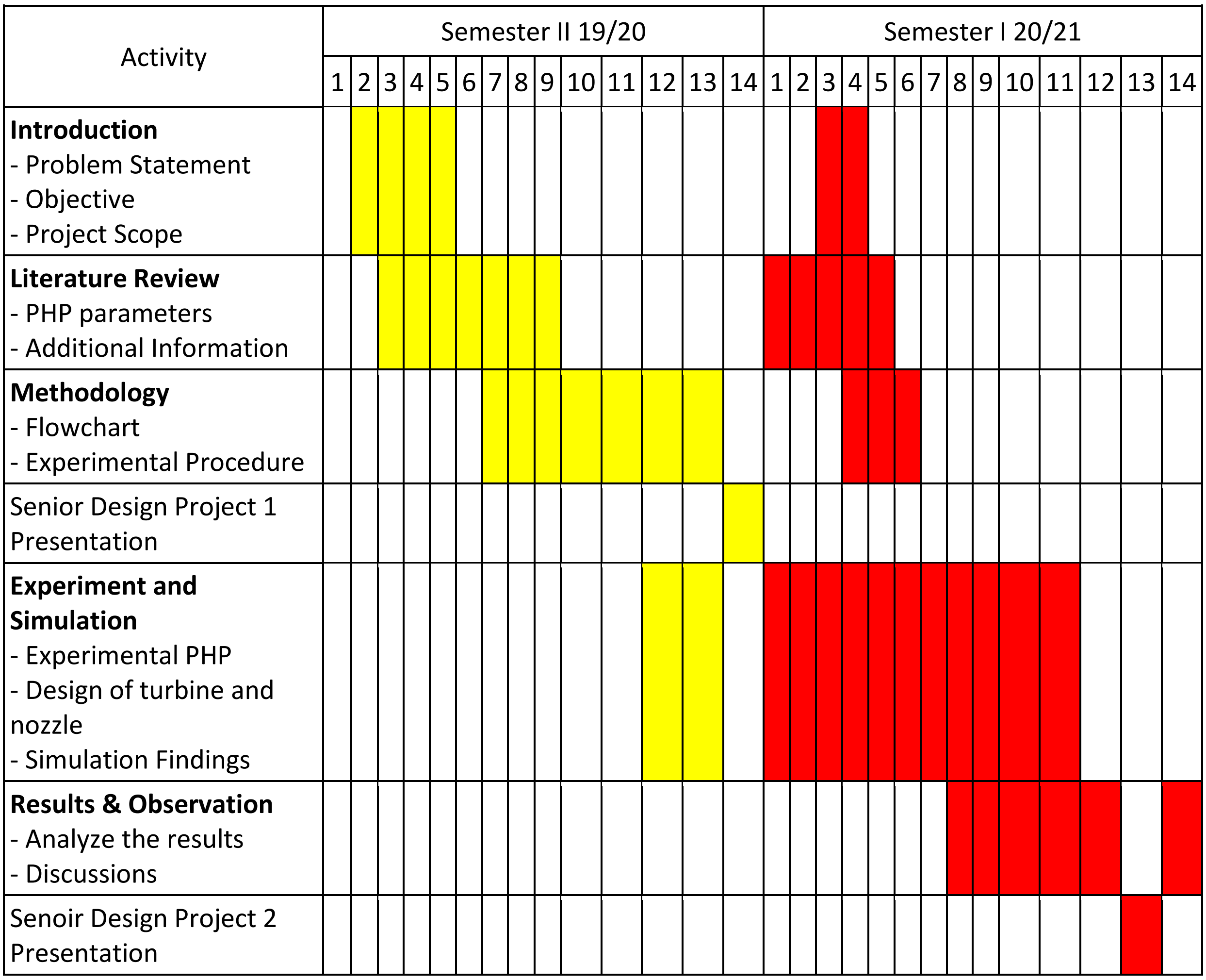
APPENDICES

Appendix A: Gantt chart



Appendix B: Project Cost

NO.	ITEM	QUANTITY	COST/ UNIT (RM)	TOTAL (RM)
1.	Acrylic Sheet A3 size 10mm	2	60.00	120.00
2.	Arduino UNO with casing	1	24.00	24.00
3.	Arduino IoT Water Solenoid Valve	1	25.50	25.50
4.	Brushed DC motor MY1016	1	90.00	90.00
5.	3D-Printer Filament 1kg	1	65.00	65.00
6.	Bearing	2	25.00	50.00
7.	Metal rod D=20mm	1	50.00	50.00
8.	LZS-15 Water Flowmeter	1	75.00	75.00
			TOTAL	RM499.50

Appendix C: Arduino Code to control and monitor water level in water tank

```
#include <LiquidCrystal.h>
int level1=A1;
int level2=A2;
int level3=A3;
int level4=A4;
int level5=A5;
int motor=6;
int a;
int b;
int c;
int d;
int e;
int r;
int m=0;
int z=111;
LiquidCrystal lcd(11,12,2,3,4,5);
void setup()
{
pinMode(level1,INPUT);
pinMode(level2,INPUT);
pinMode(level3,INPUT);
pinMode(level4,INPUT);
pinMode(level5,INPUT);
pinMode(motor,OUTPUT);
```

```
lcd.begin(16,2);
}
void loop()
{
r=digitalRead(motor);
a=analogRead(level1);
b=analogRead(level2);
c=analogRead(level3);
d=analogRead(level4);
e=analogRead(level5);
lcd.clear();
lcd.setCursor(0,1);
lcd.print("Easy HM Projects");
lcd.setCursor(0,0);
lcd.print("Water Level Monitor.");
if(e>z && d>z && c>z && b>z && a>z )
{
 {
 digitalWrite(motor,LOW);
 }
lcd.setCursor(0,0);
lcd.print("Tank is 100% FULL");
}
else
{
 if(e<z && d>z && c>z && b>z && a>z )
```

```
{
lcd.setCursor(0,0);
lcd.print("Tank is 80% FULL");
}
else
{
 if(e<z && d<z && c>z && b>z && a>z )
{
lcd.setCursor(0,0);
lcd.print("Tank is 60% FULL");
}
else
{
if(e<z && d<z && c<z && b>z && a>z )
{
lcd.setCursor(0,0);
lcd.print("Tank is 40% FULL");
}
else
if(e<z && d<z && c<z && b<z && a>z )
{
lcd.setCursor(0,0);
lcd.print("Tank is 20% FULL");
}
else
{if(e<z && d<z && c<z && b<z && a<z )
```

```
{
 {
digitalWrite(motor,HIGH);
}
lcd.setCursor(0,0);
lcd.print("Tank is EMPTY");
}
}}}}
if(r==LOW)
{
lcd.setCursor(0,0);
lcd.print("Water Pump is (OFF)");
}
else
{
lcd.setCursor(0,0);
lcd.print("Water Pump is (ON)");
}
{
delay(100);
lcd.clear();
}}
```