DESIGN AND DEVELOPMENT OF

ELECTRICAL SYSTEM ON

HYDROKINETIC TURBINES FOR HOME POWER

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UNIVERSITI MALAYSIA PAHANG

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DESIGN AND DEVELOPMENT OF ELECTRICAL SYSTEM ON HYDROKINETIC TURBINES FOR HOME POWER

HAZIRAH BINTI ROSLAN

Thesis submitted in fulfilment of the requirements for the award of the degree of
Bachelor of Engineering Technology in Electrical

Faculty of Engineering Technology
UNIVERSITI MALAYSIA PAHANG

JANUARY 2018

STATEMENT OF AWARD FOR DEGREE

1. Bachelor of Engineering Technology

Thesis submitted in fulfilment of the requirements for the award of the degree of Bachelor of Engineering Technology in Electrical.

SUPERVISOR'S DECLARATION

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ACKNOWLEDGEMENTS

Bismillahirahmanirahim..

Thankful to Allah that with the permission of grace I can completed my Senior Design Project (SDP). With no strength, patience and assistance the completion of this Project would not have been completed.

On this occasion, I would like to thank all parties involved in the success of this task. Especially to my supervisor, namely, Mr Muhamad Ridzuan Bin Radin Muhamad Amin because he has provided guidance to me during this run. Tutoring he was very helpful to me in order to complete a task that has been entrusted. Therefore, I would also like to thank the members of our family that has a lot of moral support and financial assistance to complete this task. In addition, I also thank to my colleagues for having a lot of assistance and cooperation for the realization of business accomplish this task successfully.

I also want to appreciate to my sponsors, Faculty of Engineering Technology University Malaysia Pahang (UMP), Roslan Bin Hassan (Father) and my teammates that provide some necessary financial support for me.

Many thanks to En Azmi and En Azlan, Person In Charge (PIC) in workshop for allowed me to use workshop equipment and facilities for my project. My appreciation also to all my friends, Balqis Binti Md Radzi and Widad Binti Md Jamaluddin, lecturers, technician and others who provided me with some advice and assistance.

All courtesy and service all parties involved only Allah can respond. Assalamulaikum and thank you.

ABSTRACT

Nowadays, there are many types of turbines that can found. However, most of them were applied on dam that need high water flow rates. However, in this project low water flow rates of Hydrokinetic Turbine will be use. Therefore, improvement of this mechanisme will apply in rural area. From improving Hydrokinetic Turbines this mechanisme will produce electricity to supply to rural area. Therefore, this project is proposed the application of the Hydrokinetic Turbine which is Cross-flow Water Turbine. This project is focused on small river which the water flow rates is low and suit to Cross-flow Water Turbine where the velocity and pressure is to be determined with the reading of Cross-flow Water Turbine will read by software NX 10 Nastran: Siemens PLM Software. At the end of this project, a several testing has been done to prove that an electricity produced by the turbines is sufficient to provide enough low consumption appliances.

ABSTRAK

Kini, terdapat banyak jenis turbin yang boleh ditemui. Walau bagaimanapun, kebanyakannya digunakan pada empangan yang memerlukan kadar aliran air yang tinggi. Walau bagaimanapun, dalam projek ini kadar aliran air rendah Turbin Hidrokinetik akan digunakan. Oleh itu, peningkatan mekanisma ini akan diterapkan di kawasan luar bandar. Daripada meningkatkan Turbin Hidrokinetik mekanisma ini akan menghasilkan tenaga elektrik untuk disalurkan ke kawasan luar bandar.Oleh itu, projek ini dicadangkan penggunaan Turbin Hidrokinetik iaitu Turbin Air Aliran Silang. Projek ini ditumpukan kepada sungai yang kadar aliran airnya rendah dan sesuai dengan Air Turbin Aliran Silang di mana halaju dan tekanan akan ditentukan dengan bacaan Turbin Air Aliran Silang akan dibaca oleh perisian NX 10 Nastran: Siemens PLM Software. Pada akhir projek ini, beberapa ujian telah dilakukan untuk membuktikan bahawa elektrik yang dikeluarkan oleh turbin cukup untuk menyediakan peralatan penggunaan yang rendah.

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LIST OF SYMBOLS

m	meter
m sec^{-1}	meter per second
Nm	Newton meter
kW	Kilo Watt
MW	Mega Watt
Ω	Ohm
V	Volt
kHz	kiloHertz
AH	Ampere Hour
Rpm	Rotational per minute
ω	Angular speed
rad/s	Radian per second
φ	Flux
P_L	Power delivered
P_g	Power generated
PbO2	Lead peroxide
Pb	Sponge lead
H2SO4	Dilute sulfuric acid
H2O	Water

LIST OF ABBREVIATIONS

DC	Direct current
AC	Alternating current
PMG	Permanent magnet generator
PMSM	Permanent magnet synchronous motor
EMF	Electromotive force
MPPT	Maximum Power Point Tracking
THD	Total Harmonic Distortion
PVC	Polyvinyl chloride
R_{sc}	Series winding resistance
I_{sc}	Current flowing through the series field
R_a	Armature resistance
I_a	Armature current
I_L	Load current
V	Terminal voltage
Eg	Generated emf

CHAPTER 1

INTRODUCTION

1.1 Introduction to Turbines

Across the globe, around 1.4 to 1.6 billion people have no access to electricity at all while another one billion are dependent on unreliable electrical grids. Many of those lacking access to modern energy live in rural areas, thus decentralized, off-grid energy projects will play a vital role in achieving. In order to solve this problem, water turbine had built. However people in rural area prefer things that low cost, easy to operate and long lasting. The turbines produce electricity from the free-flowing water in a river or stream and do not rely upon a water-head to produce electricity. (Bryan R.Cobb et al, 2011)

There are many type of turbine that can be found. However, this project is to gain improvement of this mechanism to apply in rural area from improving Hydrokinetic Turbine which place at river stream. The main objective of this project is to generate electricity and supply this green energy in rural area for a better living of remote community in Sungai Pahang. The hydrokinetic turbine could be submerge in the river or could be placed on the surface of the water river using the pontoon. Table 1.1 below show that classification of turbines used for pico-hydro based on hydraulic head type. The characteristic that suit to Sungai Pahang river is propeller turbine which reaction type and used depth of river below 10 meter.

Table 1.1 : Classification of turbines used for pico-hydro based on hydraulic head and type (Bryan R. Cobb et al, 2011)

TURBINE TYPE	LOW (<10m)	MEDIUM (10<50m)	HIGH (>50)
Impulse	Crossflow	Crossflow Turgo Pelton francis	Turgo Pelton
Reaction	Francis Propeller Kaplan		

The approach here is to apply the hydrokinetic water turbine to the rural area and tested to a house then electricity supply will be connected to a house which is located near to Sungai Pahang. The idea is to provide people on a solution for a rural area which is hard to get electricity supply. The project of hydrokinetic water turbine is proposed because it suit for small communities that required only a small amount of electricity.

Pahang River having the width more than 100 m and the depth could be reached more than 10 meter. The velocity of Pahang River during first sampling ranged from 0.308 to 0.582 m sec−1 and second sampling was from 0.217 to 0.484 m sec−1 (Muhamad Barzani Gasim, 2013). Usually, turbines able to produce about 1 kW to 2 kW of electrical power from range 0.217 to 0.484 m sec−1 velocity of river suitable for remote homes (Martin Anyi et al, 2009).

1.2 Problem Statement

One of the major problem faced by major rural areas around the world is lack of electrical supply because of hardness for electrical supplier to provide electrical supplies for them. However, vast amounts of untapped clean energy can be found in waterways, and this is where hydrokinetic energy, one of the best potential ways can be used for remote communities.

This problem can be solved by developing a hydrokinetic water turbine that enables generate power supply which is trasmitted from kinetic energy to electrical energy for home power in remote areas. Hydrokinetic energy is a promising new technology that still in the research and development stages. Many companies are approaching commercial distribution of various hydrokinetic energy systems, most of which are capable of providing clean energy off and on grid.

This idea also to promote green energy generation which lack of awareness among our generation nowadays and utilize the natural resources that would give benefits to all human land.

1.3 Design Objectives & Theory

The design and construction of a hydrokinetic water turbines which will generate an electrical supplies for home power in remote areas. The project is called Hydrokinetic Water Turbines for Home Power. The objectives of this project are :

- To design a hydrokinetic water turbines that able to withstand certain degree of water flow’s pressure
- To design a transmission system to supply electrical energy for home
- To measure performance study of the whole system

1.4 Project Scope

The scopes that are related to this project are studies on the power consumption generated by hydrokinetic turbines related to usage of DC generator, step-up power module, inverter and distribution board for home in rural area in order to give electrical supply for rural community.

CHAPTER 2

LITERATURE REVIEW

Figure 2.1 : The Hydrokinetic Turbines for Home Power

The Hydrokinetic Turbine can be divided into several part. Most important part is the design of blades for turbines because the blade is the main part of turbines that needs to be emphasized so that it works properly. Then, the other important part that take place is followed by shaft, debris protection and pontoons. Hence, long lasting and non-rusted materials was chosen so that it could be exposed to water for a long time.

There are two types of turbine; impulse turbine and reaction turbine. The type of turbine is selected based on the height of the standing water (head) and volume of the water available. Reaction turbine converts potential energy in pressurized water to mechanical energy. Usually, the reaction turbine used for sites with lower head and high flow rate. Unlike Impulse turbine, it converts kinetic energy from jet water to the mechanical energy. Generally, it is suitable for low speed of water supply and high head condition. The comparison between design of impulse turbine and reaction turbine are shown as in Figure 2.2.

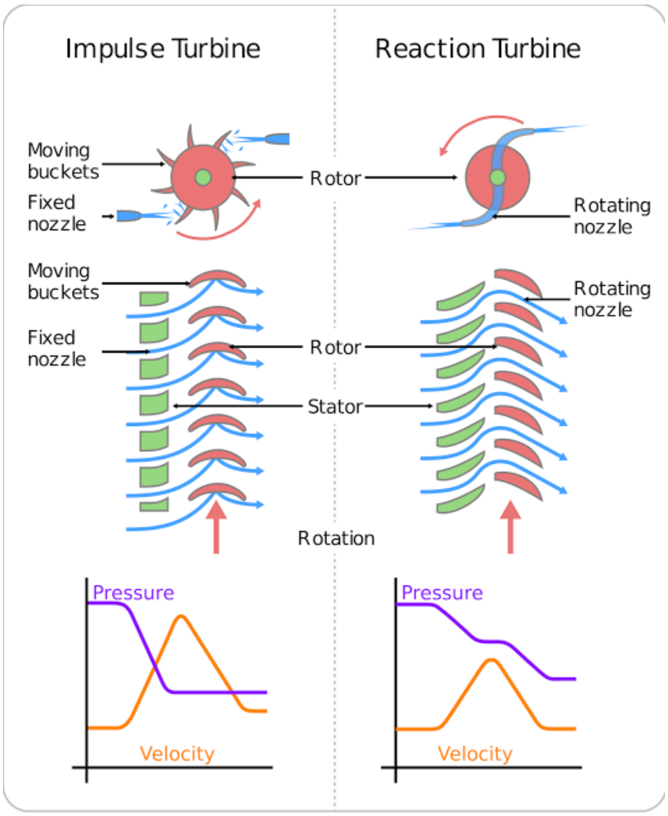


Figure 2.2 : Comparison between impulse turbine and reaction turbine (source : www.mech4study.com)

Both impulse and reaction turbines can be classified into various names such as Francis turbine, Kaplan turbine, Pelton turbine and cross-flow turbines. Table 2.1 shows that all these turbines are different in type, size, application and power output.

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

Table 2.1 : Classification of hydro power (Bartle A., 2002)

Various turbines types and applications also can be classified based on available head and flow rates as shown in Figure 2.3.

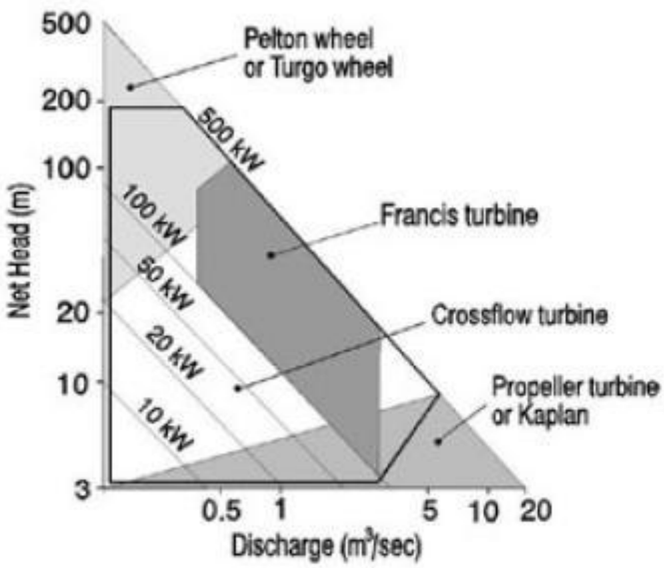


Figure 2.3 : Head Flow Ranges of Small Hydro Turbines (Caner Akcan et al, 2008)

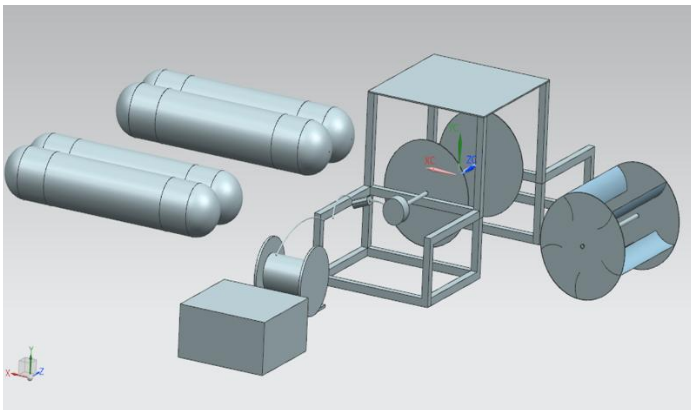


Figure 2.4 : The selected design of Hydrokinetic Turbines

In this project, the crossflow turbine (one of impulse design) as in figure 2.4 was chosen due to its capability in produce high power of energy, availability of materials in workshop and easy to fabricate. In addition, crossflow is also good performance compared to the others because the torque produced by crossflow turbines is quite high (Siti Nor Suziyana, 2013).

2.1 DC GENERATOR

An electrical generator is a rotational machine that converts the mechanical energy produced by the rotor blades (the prime mover) into electrical energy or power. This energy conversion is based on Faraday's laws of electromagnetic induction, that dynamically induces an e.m.f. (electro-motive force) into the generators coils as it rotates. DC generator may classified as series wound generators and shunt wound generators.

For series wound generators, the field windings are connected in series with armature conductors as shown in figure 2.5. So, whole current flows through the field coils as well as the load. As series field winding carries full load current it is designed with relatively few turns of thick wire.(Milivojevic N,2012).

Let,

R_{sc} = Series winding resistance

I_{sc} = Current flowing through the series field

R_a = Armature resistance

I_a = Armature current

I_L = Load current

V = Terminal voltage

Eg = Generated emf

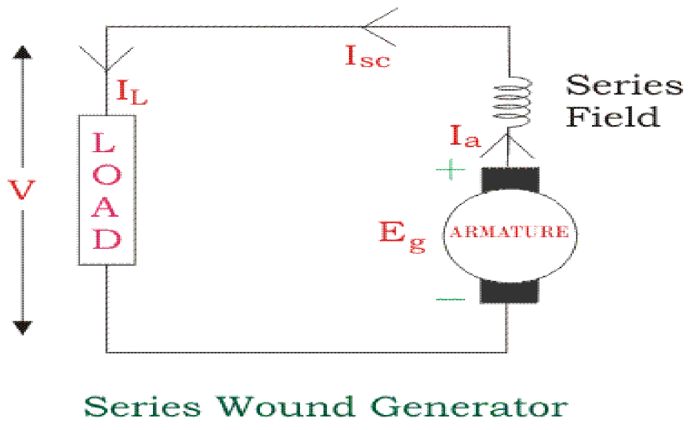


Figure 2.5 : The series wound generator

Then, $I_a = I_{sc} = I_L = I\ (say)$

Voltage across the load, $V = E_g - I(I_a \times R_a)$

Power generated, $P_g = E_g \times I$

Power delivered to the load, $P_L = V \times I$

For shunt wound generator, the field windings are connected in parallel with armature conductors as shown in figure 2.6. In shunt wound generators the voltage in the field winding is same as the voltage across the terminal.(Milivojevic N,2012).

Let,

R_{sh} = Shunt winding resistance

I_{sh} = Current flowing through the shunt field

R_a = Armature resistance

I_a = Armature current

I_L = Load current

V = Terminal voltage

E_g = Generated emf

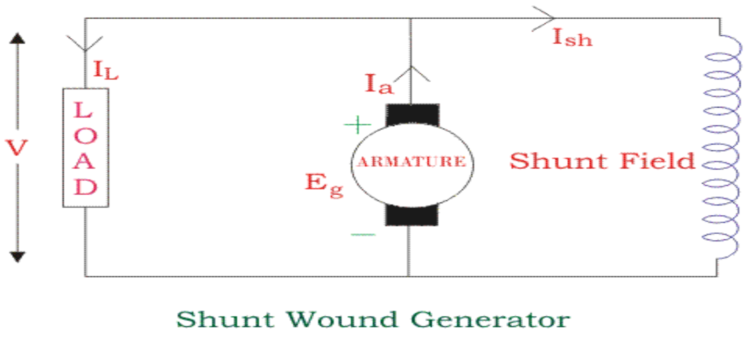


Figure 2.6 : The shunt wound generator

Here armature current I_a is dividing in two parts, one is shunt field current I_{sh} and another is load current I_L. So,

$$I_a = I_{sh} + I_L$$

The effective power across the load will be maximum when I_L will be maximum. So, it is required to keep shunt field current as small as possible. For this purpose the resistance of the shunt field winding generally kept high (100 Ω) and large no of turns are used for the desired emf.

Shunt field current, $I_{sh} = \frac{V}{R_{sh}}$

Voltage across the load, $V = E_g - I_a R_a$

Power generated, $P_g = E_g \times I_a$

Power delivered to the load, $P_L = V \times I_L$

Magnetization Curve of DC Generator

DC generator is that curve which gives the relation between field current and the armature terminal voltage on open circuit.

When the DC generator is driven by a prime mover then an emf is induced in the armature. The generated emf in the armature is given by an expression

$$E_g = \varphi P \frac{N}{60} \times \frac{Z}{A} volts = \varphi N \left(\frac{P}{60} \times \frac{Z}{A}\right) \quad or, \qquad E_g = K\varphi N \quad \left(\frac{P}{60} \times \frac{Z}{A}\right)$$

is constant for a given machine.it is replaced by K in this equation.

Where,

φ is the flux per pole,

P is the no. of poles,

N is the no. of revolution made by armature per minute,

Z is the no. of armature conductors,

A is no. of parallel paths.

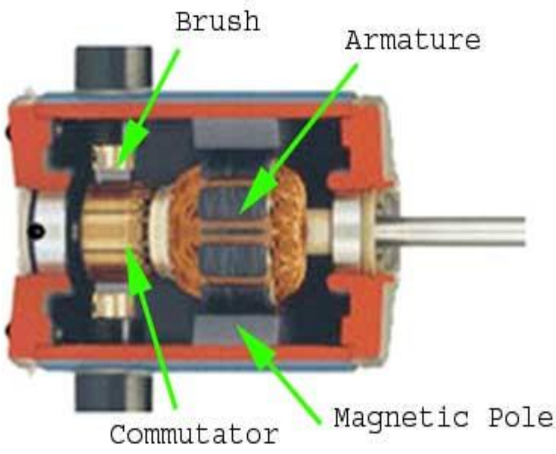


Figure 2.7 : The interior part of generator

Now, from the equation we can clearly see that the generated emf is directly proportional to the product of flux per pole and the speed of the armature :

$$Eg \propto \varphi N$$

If the speed is constant, then the generated emf is directly proportional to the flux per pole :

$$Eg \propto \varphi \text{ (N is constant)}$$

It is obvious that, as the excitation current or field current (I_f) increases from its initial value, the flux and hence generated emf is increased with the field current.

If we plot the generated voltage on the Y axis and field current on the X axis then the magnetization curve will be as shown in figure 2.8.

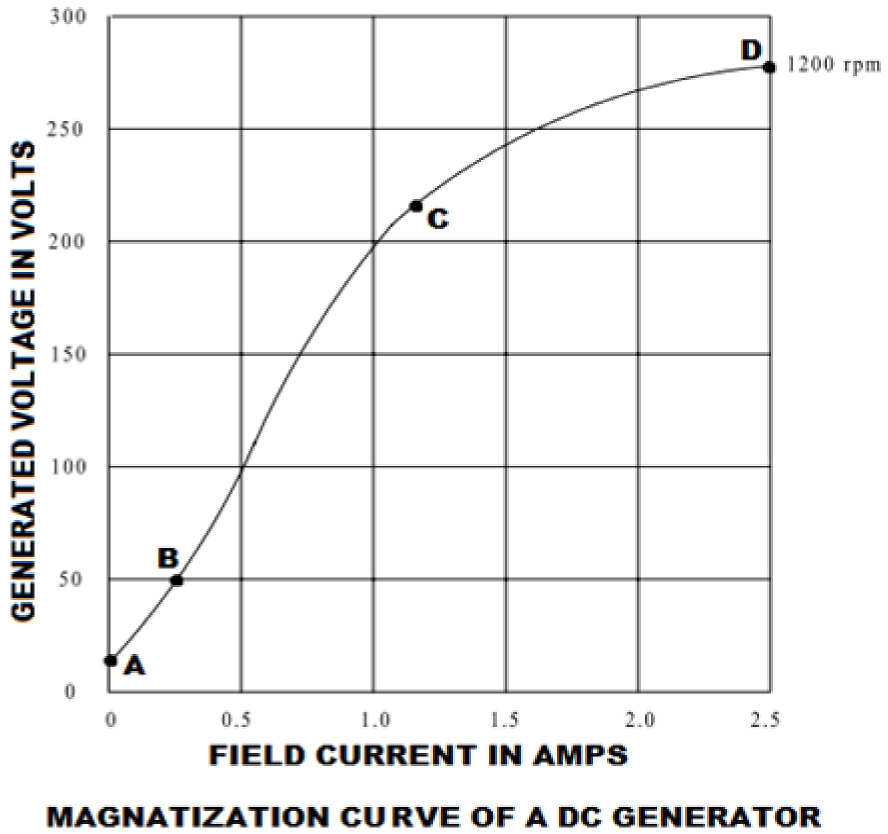


Figure 2.8 : The magnetization curve of a DC generator

Magnetization curve of a DC generator has a great importance because it represents the saturation of the magnetic circuit. For this reason this curve is also called saturation curve.

According to the molecular theory of magnetism the molecules of a magnetic material, which is not magnetized, are not arranged or aligned in definite order. When current passed through the magnetic material then its molecules are arranged in definite order. Up to a certain value of field current the maximum molecules are arranged. In this stage the flux established in the pole increased directly with the field current and the generated voltage is also increased. Here, in this curve, point B to point C is showing this phenomena and this portion of the magnetization curve is almost a straight line. Above a certain point (point C in this curve) the nu-magnetized molecules become very fewer and it became very difficult to further increase in pole flux.This point is called saturation point. Point C is also known as the knee of the magnetization curve. A small increase in magnetism requires very large field current above the saturation point. That is why upper portion of the curve (point C to point D) is bend as shown in figure.Magnetization curve of a DC generator does not start from zero initially. It starts from a value of generated voltage due to residual magnetism.

The working principle of Permanent Magnet Generator (PMG) is it rotor will rotate by the water flow and produces the voltage and correspondingly the output of the motor-generator rises in proportion to the increase of the rpm of the rotor. Thus, the motor-generator designed to produce the desired output voltage when the rotor is at low speed comes to yield too high voltages to control them properly. As opposed to the event stated just earlier, the way to raise the output voltage at a low speed needs to either make the permanent magnet large in size or increase the current and also increase the number of loops or turns in the winding to intensify the strength of the magnetic field at the stator side with the result of yielding great torque.(M.Salah.,at el 2010).

2.2 BATTERIES

Batteries are defined as current sources of chemistry. An active ingredient and electrolyte set is the basis of current chemical resource action. This function works in the form of cells that contain positive and negative electrodes and electrolytes in individual enclosures in batteries and accumulators.

The cells are the source of direct current and depend on the type of chemical reaction that can be divided into:

1. The primary cell in which the electricity generation is followed by irreversible chemical reactions. They are not designed to be imposed by any other electrical source.
2. The secondary cell in which the generation of electricity occurs by a reversible chemical reaction and is designed to be imposed by other electrical sources.

The batteries such as the lithium-polymer batteries as shown in Figure 2.15 are the sources of electrical energy generated by the direct transformation of chemical energy, which consists of one or more primary cells that cannot be reused, including housing, ends and marks. The collector is a source of chemical power that allows the storage and release of electricity which is abundant as a result of reversible energy transformation. This is the source of electricity generated by the direct transformation of chemical energy, consisting of one or more secondary reusable cell. Various bacteria and accumulators are currently used. The following batteries can be distinguished:

1. Zinc-carbon (zinc-manganese with chloride electrolyte)
2. Zinc-mercury
3. Silver-zinc
4. Alkaline (manganese-zinc with alkaline electrolyte)
5. Lithium.

For the lithium batteries include a lot of subtypes, which combines the use of lithium or its compounds as anodes. Among the compounds used on the cathode include minibars and safes manganese oxide (IV), thiol chloride, sulfur oxide (IV), iodine, chromate (VI), silver and others. Among accumulators are used:

1. Lithium-polymer
2. Lithium-ion
3. Nickel-iron
4. Nickel-cadmium
5. Nickel-zinc
6. Nickel-metal-hydride
7. Silver-zinc
8. Lead-acid

The lead-acid battery is used to store the electrical energy generated by turbines. The energy created by the hydrokinetic turbine, can be consumed by a load or but must accumulate in batteries. In the case of the turbine, all the energy generated passes 12V battery, and then connected to an inverter, so that no energy consumed by the inverter is accumulated in the batteries. When there is low waterflow, it is possible that this generating electricity from another source. It is called the device battery that stores electrical energy, using electrochemical methods and subsequently returns almost completely. Is secondary electrical generator, namely a generator that can not run without being electricity is supplied in advance by so-called charging. (Daniel Munarrizb Antona,2013). Lead-acid battery is the battery formed by the electrodes of lead, and it is many used in automobiles.

Lead acid batteries are created batteries 2V, in the case of the commercial battery, to offer a practical output voltage, 2V has several cells connected in series. Figure 2.9 shows the internal and external structure of Pb-acid battery for car, which shows the serial connection of the cells, which are physically separated by partitions within the box that contains them. Each cell is composed of several positive and negative plates, those with intermediate separators. All plates like polarity within a cell are connected parallel. The use of multiple plates same polarity to increase the active surface of a cell, increasing its capacity. In order to accumulate the excess electrical energy generated by hydrokinetic turbines, the most suitable battery should be considered is lead-acid battery.

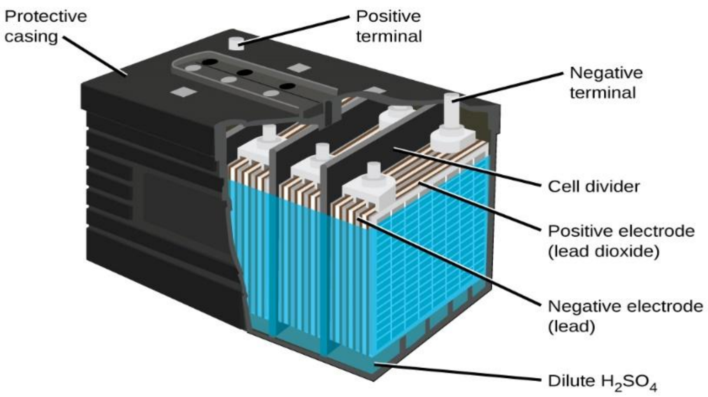


Figure 2.9 : Internal part of Lead-acid battery (Daniel Munarrizb Antona,2013)

The voltage provided by a battery is direct current. To charge it needs a DC generator that will be used for hydrokinetic turbines, which shall be connected to polarity correct the generator positive battery positive and negative to negative generator battery. In order to force a load current, the voltage of the generator should be higher than the battery.

The storage battery or secondary battery is such battery where electrical energy can be stored as chemical energy and this chemical energy is then converted to electrical energy as when required. The conversion of electrical energy into chemical energy by applying external electrical source is known as charging of battery. Whereas conversion of chemical energy into electrical energy for supplying the external load is known as discharging of secondary battery. During charging of battery, current is passed through it which causes some chemical changes inside the battery. This chemical changes absorb energy during their formation.

Figure 2.10 : The Lead-acid battery

When the battery is connected to the external load, the chemical changes take place in reverse direction, during which the absorbed energy is released as electrical energy and supplied to the load.

Materials used for Lead Acid Storage Battery Cells

The main active materials required to construct a lead acid battery are

1. Lead peroxide (PbO_2).
2. Sponge lead (Pb) and
3. Dilute sulfuric acid (H_2SO_4).

1. Lead Peroxide (PbO_2)

The positive plate is made of lead peroxide. This is dark brown, hard and brittle substance.

2. Sponge Lead (Pb)

The negative plate is made of pure lead in soft sponge condition.

3. Dilute Sulfuric Acid (H_2SO_4)

Dilute sulfuric acid used for lead acid battery has ration of water : acid = 3:1.

The **lead acid storage battery** is formed by dipping lead peroxide plate and sponge lead plate in dilute sulfuric acid. A load is connected externally between these plates. In diluted sulfuric acid the molecules of the acid split into positive hydrogen ions (H^+) and negative sulfate ions (SO_4^{--}). The hydrogen ions when reach at PbO_2 plate, they receive electrons from it and become hydrogen atom which again attack PbO_2 and form PbO and H_2O (water). This PbO reacts with H_2SO_4 and forms $PbSO_4$ and H_2O (water).

$$PbO_2 + 2H \rightarrow PbO + H_2O$$

$$\frac{PbO + H_2SO_4 \rightarrow PbSO_4 + H_2O}{PbO_2 + H_2SO_4 + 2H \rightarrow PbSO_4 + 2H_2O}$$

SO_4^{--} ions are moving freely in the solution so some of them will reach to pure Pb plate where they give their extra electrons and become radical SO_4. As the radical SO_4 cannot exist alone it will attack Pb and will form $PbSO_4$. As H^+ ions take electrons from PbO_2 plate and SO_4^{--} ions give electrons to Pb plate, there would be an inequality of electrons between these two plates. Hence there would be a flow of current through the external load between these plates for balancing this inequality of electrons. This process is called discharging of lead acid battery. The lead sulfate ($PbSO_4$) is whitish in colour. During discharging,

1. Both of the plates are covered with $PbSO_4$.
2. Specific gravity of sulfuric acid solution falls due to formation of water during reaction at PbO_2 plate.
3. As a result, the rate of reaction falls which implies the potential difference between the plates decreases during discharging process.

Now we will disconnect the load and connect $PbSO_4$ covered PbO_2 plate with positive terminal of an external DC source and PbO_2 covered Pb plate with negative terminal of that DC source. During discharging, the density of sulfuric acid falls but there still sulfuric acid exists in the solution. This sulfuric acid also remains as H^+ and SO_4^{--} ions in the solution. Hydrogen ions (cation) being positively charged, move to the electrode (cathode) connected with negative terminal of the DC source. Here each H^+ ion takes one electron from that and becomes hydrogen atom. These hydrogen atoms then attack $PbSO_4$ and form lead and sulfuric acid.

$$PbSO_4 + 2H \rightarrow H_2SO_4 + Pb$$

SO_4^{--} ions (anions) move towards the electrode (anode) connected with positive terminal of DC source where they will give up their extra electrons and become radical SO_4. This radical SO_4 cannot exist alone hence reacts with $PbSO_4$ of anode and forms lead peroxide (PbO_2) and sulfuric acid (H_2SO_4).

$$PbSO_4 + 2H_2 + SO_4 \rightarrow PbO_2 + 2H_2SO_4$$

Hence by charging the lead acid storage battery cell,

1. Lead sulfate anode gets converted into lead peroxide.
2. Lead sulfate of cathode is converted to pure lead.
3. Terminal; potential of the cell increases.
4. Specific gravity of sulfuric acid increases.

2.3 INVERTER

A power inverter, or inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source. A power inverter can be entirely electronic or may be a combination of mechanical effects (such as a rotary apparatus) and electronic circuitry. There are 3 types of inverter :

2.3.1 Square-wave Inverter

Square-wave output high-frequency resonant Inverter can operate in two major modes: (a) continuous current mode or (b) discontinuous current mode. Each of these modes can enter into a number of sub-modes and each sub-mode can be divided into different intervals for the purpose of analysis. The different sub-modes, the operating details and their analysis for the above two major modes are presented in detail in sections (a) and (b). Wherever possible, closed form solutions are obtained based on the simplifying assumptions of section 2. In the analysis presented it is assumed that a half bridge inverter is used in the converter. However the analysis can easily be extended to full bridge Inverter.

(a) Continuous Current Mode

Switches are triggered before the Inverter output current reaches zero as in figure 2.9 (a). There is no output voltage control in this mode. Hence this mode is not useful when used in the DC/DC converter. However this mode is of importance in the case of its use in a "line current modulated utility Interfaced high frequency link power converter", where the high frequency resonant Inverter works with fixed frequency (A.K.S Bhat,1985)

(b) Discontinuous Current Mode

In the case of discontinuous current mode, depending on the triggering frequency, the inverter can operate in 3 sub-modes as in figure 2.11 (b).

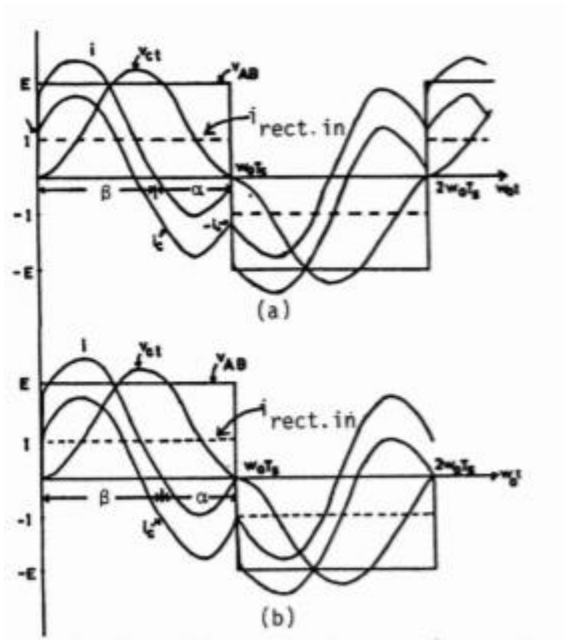


Figure 2.11 : Operating waveforms of square-wave output resonant inverter in Continuous current mode of operation, (a) submode 1 (b) submode 2.

2.3.2 Sine Wave Inverter

A power inverter device which produces a multiple step sinusoidal AC waveform is referred to as a sine wave inverter. To more clearly distinguish the inverters with outputs of much less distortion than the modified sine wave (three step) inverter designs, the manufacturers often use the phrase pure sine wave inverter. Almost all consumer grade inverters that are sold as a "pure sine wave inverter" do not produce a smooth sine wave output at all, just a less choppy output than the square wave (two step) and modified sine wave (three step) inverters.

The evolution of the current-mode sinewave inverter (CMSWI) follows from the judicious application of duality to the conventional half bridge series inverter shown in Figure 2.11 (a) (N. Mapham,1967). The result is shown in Figure 2.11 (b).

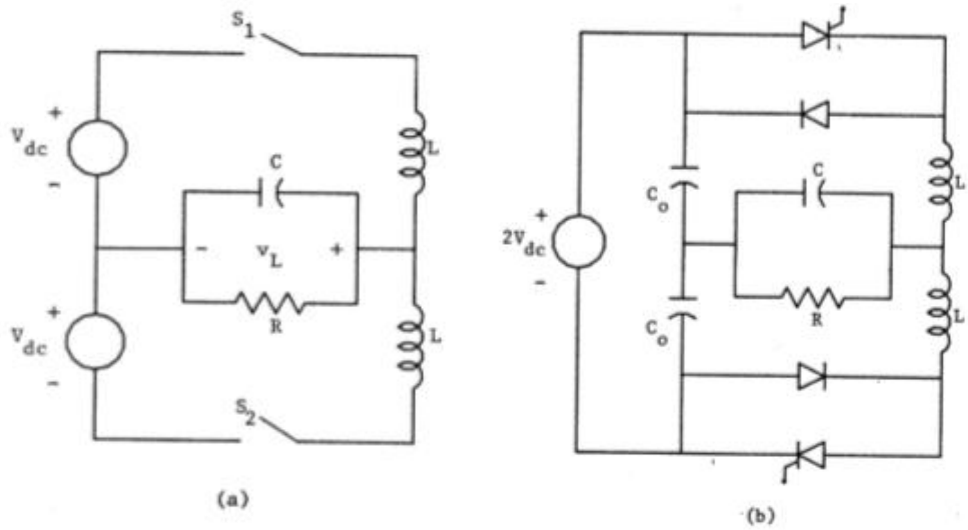


Figure 2.12 : (a) Half-bridge series inverter structure
(b) Half-bridge series inverter practical implementation

Certain consequences of this transformation are not immediately apparent from the basic topology shown in Figure 2.12 (a). The complete transformation requires that duality be applied also to the operating sequence of the switches S1 and S2. Thus the switching sequence for the CMSWI is the complement of that for the series inverter. There is an even subtler issue here, however. In the series inverter the times at which S1 and S2 close is an independent variable, i.e., they are determined by a control signal. The times at which they open is determined by the power circuit behavior. In the CMSWI implementation shown in Figure 2.12 (b) the circuit behavior determines when the switches close and control is exercised on their opening time. As with the series inverter, a general analytic description of the parallel inverter is tedious and not particularly insightful. A qualitative description of the circuit of Figure 2.12 (a) follows. If S1 and S2 are initially closed and S1 opens, the current I_L will build up sinusoidal to a value approaching 2Idc. The voltage across C1 will execute a complete (but decaying) sinusoidal cycle at the completion of which Si closes. The switch S2 is next opened and a complementary cycle occurs. (J. G. Kassakian,1979)

2.3.3 Modified sine wave Inverter

Modified sine wave inverters can be classified as low frequency (LF) or high frequency (HF), according to the switching frequency and transformer frequency adopted. A LF modified sine wave inverter first converts the DC source into a low voltage AC wave form and then uses a low frequency transformer (100 or 120 Hz) to step up the low magnitude AC voltage to the 120VAC. The topology of the LF modified sine wave inverter is simple but the size and weight are large due to the large LF transformer. On the other hand, as shown in Figure 2.13, a HF modified sine wave inverter typically contains two stages. The first stage is a step-up DCDC converter with HF switches, HF transformer, and rectifier that boosts the DC source to a high DC voltage (VDC). The second stage is a bridge topology circuit that converts the VDC to 120VAC. Compared with LF modified sine wave inverters, HF modified sine wave inverters with the same power rating are lighter, smaller and more compact due to the use of an HF transformer. (K. Brabandere at el.,2004)

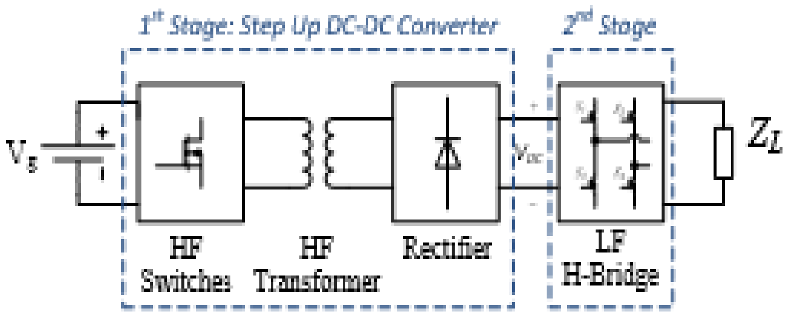


Figure 2.13 : Topologies of high frequency (HF) modified sine wave inverters

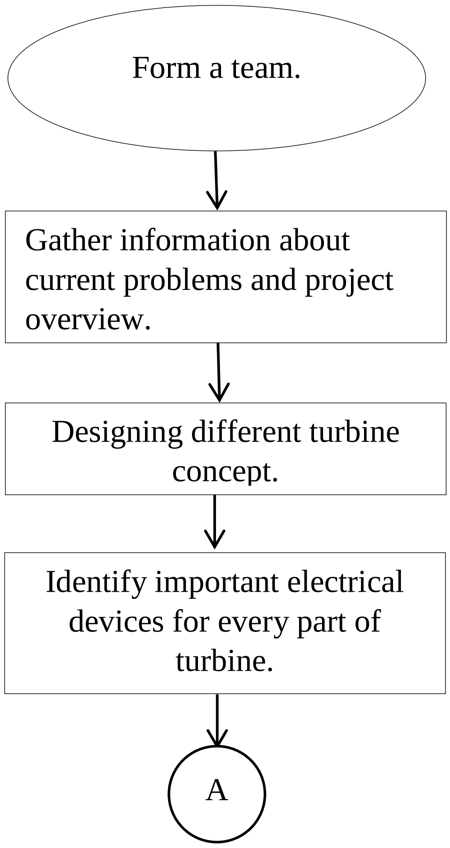
CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter explained in details on the procedures for the implementation of the electrical supply system in the Hydrokinetic Turbines. The methods used in this chapter are aimed to achieve the objectives of the project which will give satisfying results on the performance of electrical system in the Hydrokinetic Turbines.

3.2 FLOW CHART OF PROJECT MILESTONE



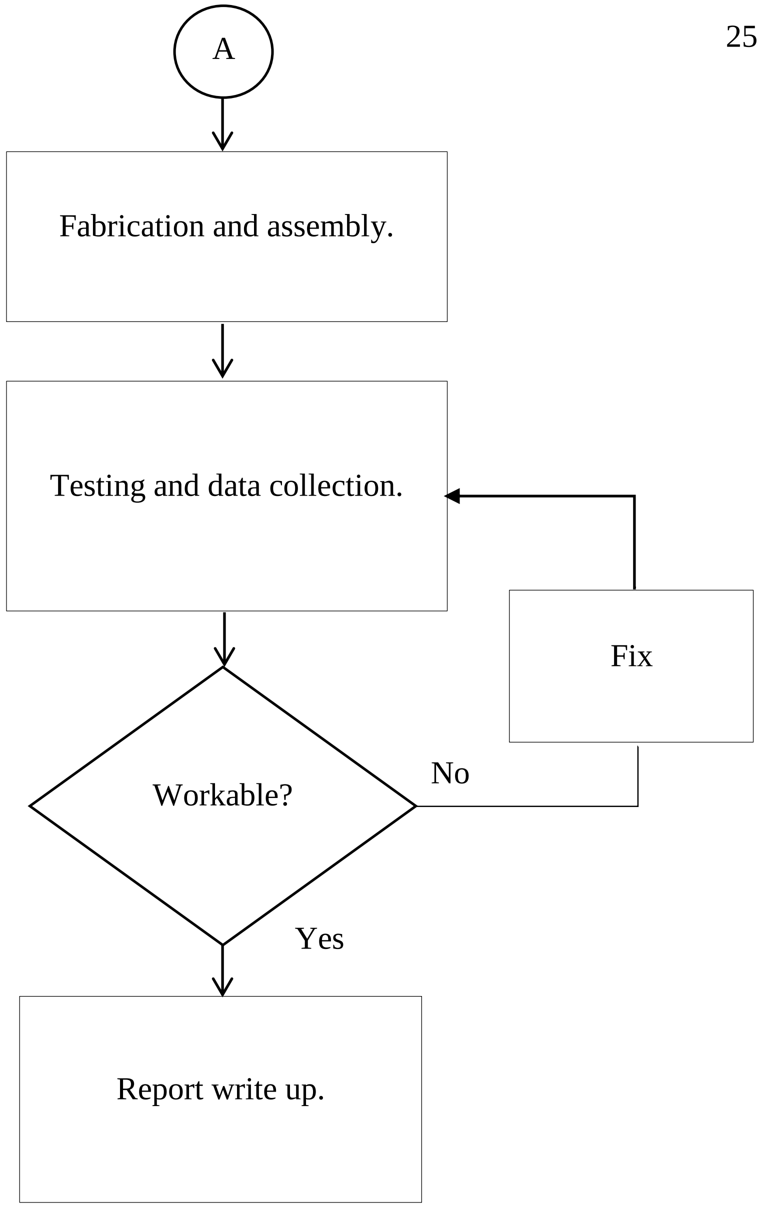


Figure 3.1 : Flow chart of project milestone

3.3 SELECTION OF ELECTRICAL COMPONENTS

3.3.1 BATTERY

The need for energy storage in electricity networks is becoming increasingly important as more generating capacity uses renewable energy sources which are intrinsically intermittent. The spinning reserve of large networks is becoming less able to maintain power quality with increased renewable inputs and the strategies needed to optimize renewable input without curtailment or other measures are driving a move to energy storage. Electrochemical energy storage in batteries is attractive because it is compact, easy to deploy, economical and provides virtually instant response both to input from the battery and output from the network to the battery (PJ Hall at el, 2008).

Batteries are devices that convert stored chemical energy into electrical energy. Batteries are either intended for onetime or rechargeable use. They use a variety of different chemicals and metal components to develop and convert energy, such as zinc, carbon, alkaline, gels, and fiberglass. One of the major rechargeable battery types is the valve-regulated lead-acid (VRLA) battery, also known as the sealed lead-acid (SLA) battery.

Table 3.1 : Comparison between Lead acid Battery and Lithion Ion Battery

Comparison Table

Item \ Battery		NAS (Base)	Lead-Acid (Current)	Lithium Ion	Ni-H
Continuous Discharge Duration with rated output		6 hours	2 hours	3 hours	2 hours
Expected Lifetime (at standard conditions)		15 years	3 to 5 years	10 years	7 years
Size	MWh(1MW x 6h)	1	3 times	2 times	3 times
Weight	MWh(1MW x 6h)	1	6 times	2 times	6 times
Price	MWh x 15years	1	3 to 5 times	8 times	6 times
Notes	Self Discharge	No	Yes	Yes	Yes
	Memory Effect	No	No	No	Yes

Note: These data are typical values and change by the manufacturers

Based on Table 3.1, it shows that the lithion ion is better in size,weight, lifetime and price compared to SLA battery. But because there is budget constrain so this project need to use SLA battery was selected for keeping the energy produced by the generated turbines.

3.3.2 DC GENERATOR

DC Permanent Magnet Motor Generator (PMG) are mostly used for wind and water turbines.The PMG system is intentional for converts mechanical energy obtained from an external source into electrical energy as the output. The PMG was chosen because the cost of this generator is affordable yet it offers quite satisfying results.

Many permanent magnet motor drives use an open loop form of torque control, based on the assumption that output torque is proportional to applied current. Many high-performance permanent magnet motors use surface-mounted magnets on a rotor with a large rotor- stator airgap. The large airgap ensures minimum armature effect on the rotor field from the stator. These machines are also designed with low saliency so that the first two effects are minimized. Generally if the waveforms of the phase current reference and the phase electromotive force (EMF) are perfectly matched, torque ripple is minimized.

In this project, a hydrokinetic turbines was built based on this type of generator.

Figure 3.2: 12V DC Permanent Magnet Generator

Generator Specification:

Voltage : 12 VDC

Permanent Magnet : Rare Earth Neodymium magnets

Moisture /Corrosion Resistance : Yes, sealed exterior, ball bearing, coated rotor

Shaft Daimeter : 17mm

Body Material : Aluminium Alloy & Steel

Rotor Diameter : 10cm (4 inches)

Length : 9cm (3.5 inches)

Weight : 2.44kg (5.4 lbs)

Mount : on face plate

Cable Length : approx. 33cm (13inch)

Rotation : Bi-directional, recommend clockwise

3.3.3 12VDC TO 220VAC INVERTER

Inverter converts the available output of the generator into a voltage with constant amplitude and frequency (Steinbring et al.,2012).This inverter - fed induction machine drive is controlled according to the performance curves of the turbine. The turbine emulator proposed in this work is used to emulate the behaviour of a small hydro turbine in laboratory applications so that no water laboratory is required. In this way, the mechanical power at the shaft of the Permanent Magnet Synchronous Motor (PMSM) - generator is not provided by a turbine but by the induction machine drive that exhibits the steady state behaviour of the hydro-turbine.

A Z-source converter is an unique x-shaped impedance network called Z-source impedance network that couples the converter main circuit to the power source. The converter may be of all conversion types - if it is of ac-to-dc type, the z-source converter is called z-source inverter. Since 2003 when this recently conversion concept appeared (F.Z. Peng, 2003), it proved able to solve many conversion problems. The Z-source converter employs a unique impedance network (or circuit) to couple the converter main circuit to the power source, thus providing unique features that cannot be observed in the traditional voltage-source and current-source converters where a capacitor and inductor are used, respectively. The Z-source converter overcomes the conceptual and theoretical barriers and limitations of the traditional voltage-source converter and current-source converter and provides a novel power conversion concept. The Z-source concept can be applied to almost all dc-to-ac, ac-to-dc, ac-to-ac and dc-to-dc power conversion (Fang, 2003).

The next part to consider in choosing a suitable inverter for the electrical supply for home is the 500watt 12VDC to 220VAC inverter.

Figure 3.3 : DC to AC Inverter

Here are the specifications of chosen inverter:
Input voltage: DC 12V
Output voltage: AC 220V 50 Hz
Output power: 500W
USB port output voltage: DC 5V
Output waveform: Modified sine wave

Low voltage alarm (no load): DC 10.2~10.8V

Low voltage shutdown (no load): DC 9.7~10.3V

High voltage shutdown (no load): DC 14~16V

Peak efficiency: > 90%

Item size: Approx. 14.5 * 9 * 5.5cm / 5.7 * 3.5 * 2.2in

Item weight: Approx. 408g / 14.4oz

Package size: Approx. 24 * 17.5 * 8cm / 7.3 * 5.9 * 2.4in

Package weight: Approx. 570g / 1.26lb

3.3.4 STEP-UP POWER MODULE

This is a DC to DC voltage step up switching module, or sometime is called boost regulator. The maximum input current is at 5A and it is based on LM2587 Boost IC (Maximum efficiency is 92%) and the output voltage is adjustable via on board multi-turn potentiometer.

Input voltage can should be lower than output voltage, please turn the multi-turn potentiometer clock wise to increase the output voltage. Since it is not buck converter (step down), you need to make sure the output voltage is higher than input voltage. Input voltage can be vary from 3.5V to 30V and the output voltage can be adjusted from 4.0V to 30V. Continuous output current can be as high as 3A.

Example application is to boost 5V from USB to power 12V devices.

Figure 3.4 : Step Up Power Module

Features:

- Nature of the module: Non-isolated boost (Boost)
- Rectification: Non-synchronous rectification
- Input voltage: 3.5V - 30V
- Output voltage: 4V - 30V
- Output current: 3A (maximum)
- Maximum output power: 20W
- No polarity protection
- No short circuit protection
- Transfer efficiency: 92% (maximum)
- Switching frequency: 100KHz
- Output ripple: 50mV (maximum)
- Load regulation: ±0.5%
- Voltage regulation: ±0.5%
- Operating temperature: -40°C to +85°C
- Dimension: 38 x 52 x 20mm (L x W x H)

  Typical output (for reference):
- Input 5V, Output 12V / 1.2A
- Input 5V, Output 24V / 0.6A
- Input 7.4V, Output 12V / 2A
- Input 7.4V, Output 19V / 1.2A
- Input 7.4V, Output 24V / 0.9A
- Input 12V, Output 19V / 2A
- Input 12V, Output 24V / 1.5A

3.3.5 MAIN DISTRIBUTION BOARD

A Main Distribution Board (MDB) is where the electrical supply is distributed from within the building. The main supply cable comes into the board and is then distributed to the breakers and from there to all the circuits, e.g. lights, plugs. It usually houses all the contact breakers, earth leakage unit and may house items such as a door bell transformer and timers. Various sizes of distribution boards are available. For this project, single phase of DB was chosen to distribute electrical supply for home at rural area. (source : safehousesa.co.za)

Each distribution board must be controlled by a switch disconnector (mains or main switch). The switch disconnector should:

- Be mounted in or next to the distribution board.
- In the case of the main or first distribution board of an installation, be labelled as “main switch”.
- In the case of a sub-distribution board, be labelled as “sub-main switch” or “main switch” if the board is labelled “sub-board”.
- In the case where an alternative supply is installed (emergency supply, uninterruptible power systems (UPS), etc.), be labelled as required.
- Have a danger notice on or near it. The danger notice should give instructions that the switch disconnector be switched off in the event of inadvertent contact or leakage.

3.4 PROCESS OF INSTALLATION

Figure 3.5 and 3.6 shows the process of installation electrical component such as wiring in main distribution board, bulb and bulb holder, 3 way 1 gang switches and plugs. All these component was set up in one box.

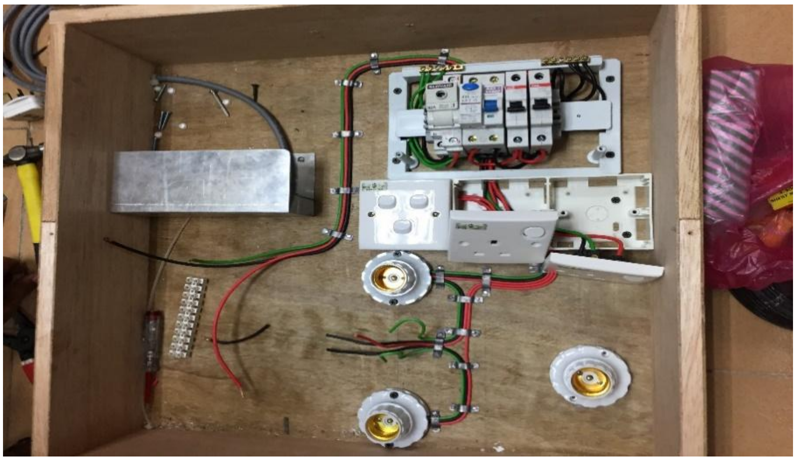


Figure 3.5 : Installation of electrical components

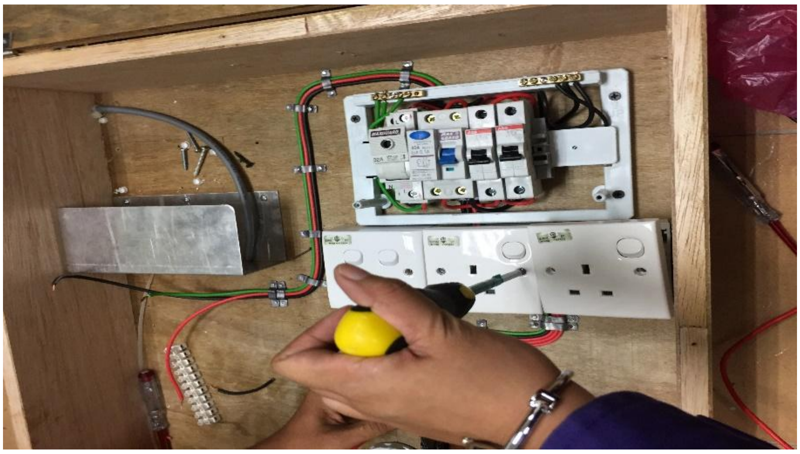


Figure 3.6 : Electrical system installation process

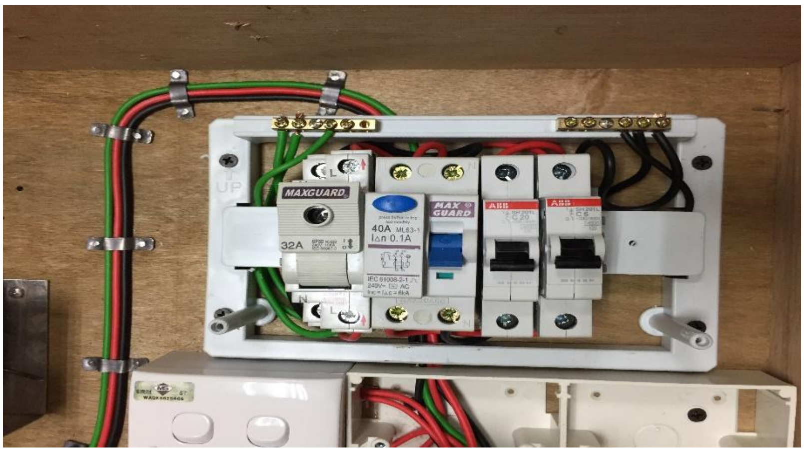


Figure 3.7 : Complete installation of cables in Main Distribution Board

Figure 3.7 shows wiring installation using earth, neutral and live cables into main distribution board and connected to 3 way 1 gang switch and plugs. These wiring illustrate same as distribution board at home.

Figure 3.8 shows the block diagram of Hydrokinetic Turbines for Home Power. The turbines are placed in water currents. The resulting submersibles of water flow will produce mechanical energy. The resulting mechanical power is channeled to the generator and it produces electrical energy. The resulting energy will be discharged through step up to increase the voltage input value. This step up can accept the voltage input of 3 V to 30 V while the rated output voltage is 4 V to 30 V. The next flow flows into the battery for the storage process. Battery capacity is 7.2 AH. Voltage stored in the battery is then discharged through an inverter which can convert from 12 V DC to 220 V AC. the value of 220 V AC is required to turn on the home energy system using main distribution board or fuse box.

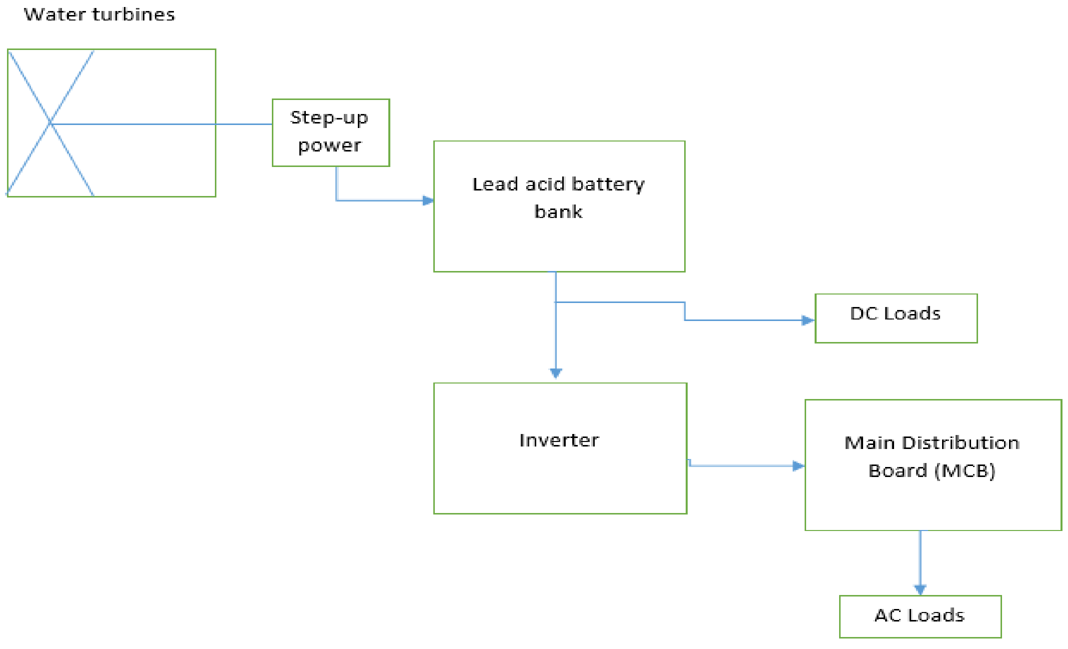


Figure 3.8 : Block diagram of Hydrokinetic Turbines for Home Power

Following are the schematic diagram for hydrokinetics turbines system :

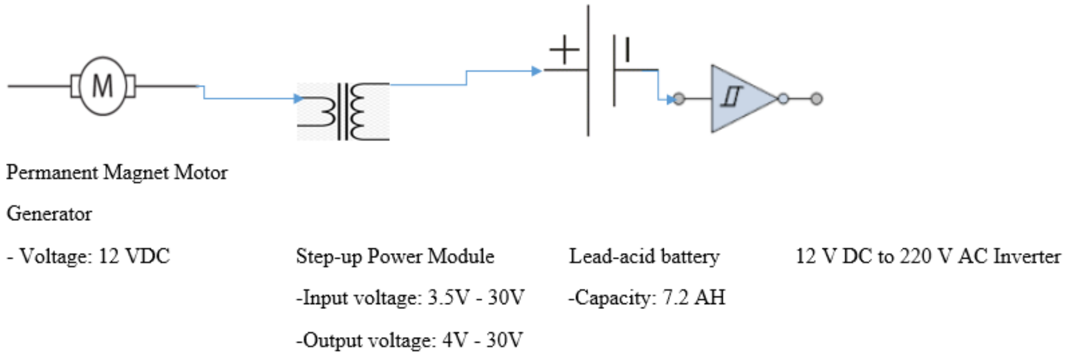


Figure 3.9 : Schematic diagram for Hydrokinetic Turbines for Home Power

CHAPTER 4

RESULT AND DISCUSSION

4.1 RESULTS

In order to accomplish the project, the contribution from other team member is crucial. As a result, the prototype of hydrokinetic turbines has been built as Figure 4.1.

Figure 4.1 : The prototype of hydrokinetic turbines

Figure 4.2 shows the value of rotational of turbines in rpm. These results was obtained during testing for 6 hours in water flow of river. Based on the graph, there is a sharp increase in rpm values from the second to fourth hours. This is happen due to the presence of heavy rainfall at the testing site.

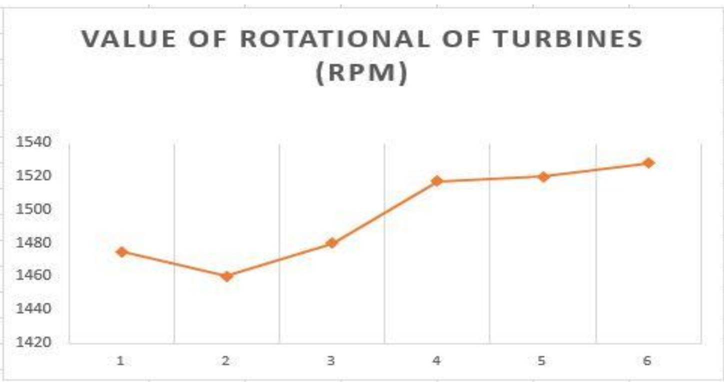


Figure 4.2 : The values of rotational of turbines in unit rpm during 6 hours of testing

Figure 4.3 shows the values of voltage generated by turbines in unit V. The resulting graph shows the voltage increases is in line with the increases values of rotational of turbines in unit rpm as in Figure 4.2.

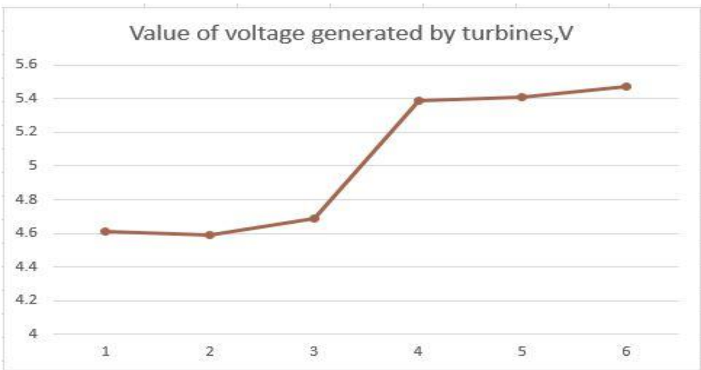


Figure 4.3 : The values of voltage generated by turbines in unit V

Table 4.1 shows the results of voltage values after step up the input voltage and angular speed was obtained after 6 hours of testing. The value of voltage was measured by using multimeter meanwhile the values of angular speed was measured using tacometer in unit rad/s.

Table 4.1 : The values of voltage after step-up input voltage and angular speed

Hour	Value of voltage generated by turbines,V (input)	Voltage values after step-up the input voltage, V (output)	ω, angular speed in (rad/s)
1	4.61	12.2	154.46
2	4.59	11.9	152.89
3	4.69	12.9	154.99
4	5.39	13.6	158.86
5	5.41	13.8	159.17
6	5.47	14.4	160.01

Figure 4.4 : The voltage value of battery before charge

Figure 4.5 : The voltage value of battery after charge

During testing at site, the value of charged battery increases 40% where initial value of battery measured about 6.95 V and increases to 11.7 V in 6 hours.

Thus, the average capacity of battery charge in one hour is 0.7917 V

For duration of lead acid battery to fully charged = $\frac{14.9\ V}{0.7917\ V}$

= 18.82 Hours

The fully charged battery (maximum 14.9 V) will support 3 bulbs (3W each) and one standing fan (75W) in ± 8 hours.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

In conclusion, this research project has performed the development of green energy in hydrokinetic turbines for home power with the suitable specifications and requirements by using quality and economical equipment such as lead acid battery, permanent magnet motor generator, step-up power module and DC to AC inverter. Besides, the custom-made hydrokinetic turbines are able to generate electrical energy for home power specify for rural area.

5.2 RECOMMENDATIONS

For future work, the system in Hydrokinetic Turbines should be equipped and upgraded with gearing system to increase the voltage generated by turbines in low speed. Besides, smaller the scale of turbine so that it will more easier to bring anywhere as it needs to bring and placed at rural area.

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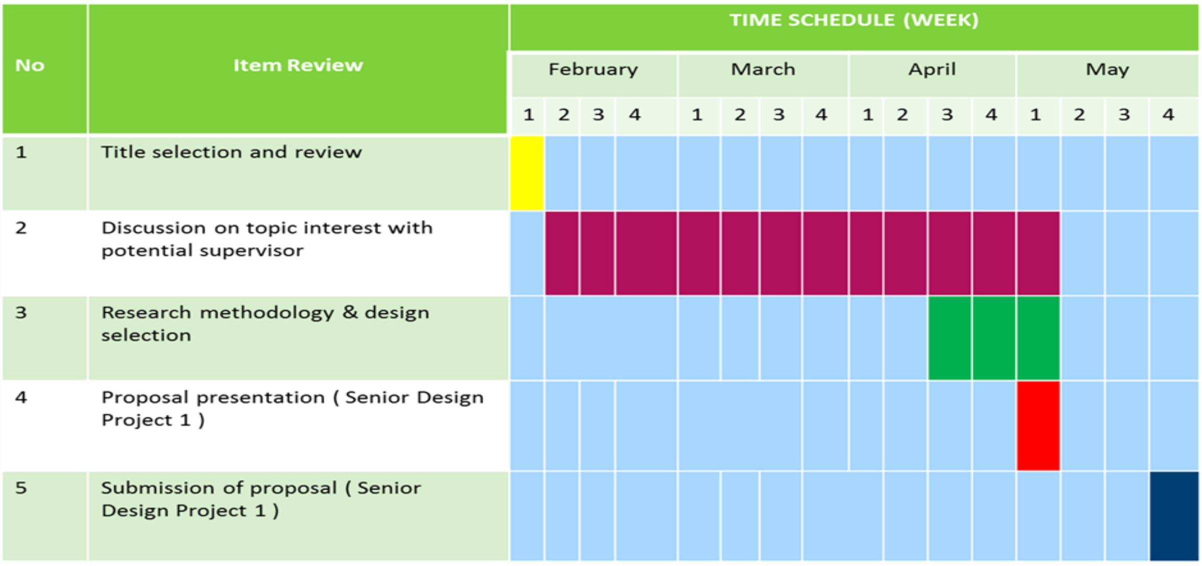
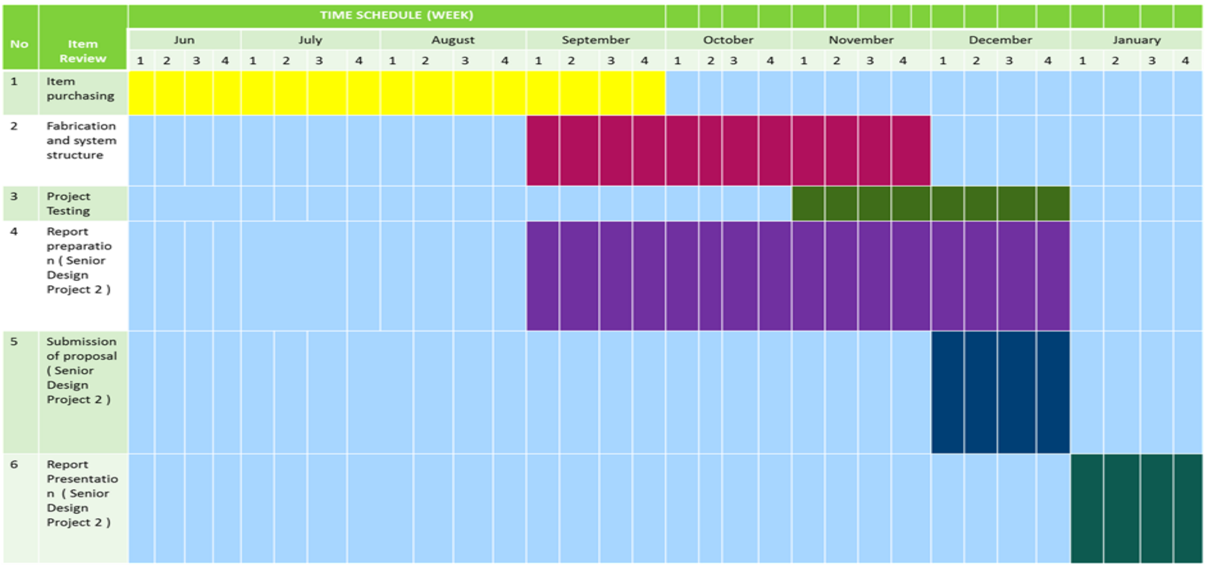
APPENDIX A

GANTT CHART

GANTT CHART FOR SENIOR DESIGN PROJECT 1 (SDP 1)



GANTT CHART FOR SENIOR DESIGN PROJECT 2 (SDP 2)



APPENDIX B

COST ANALYSIS

NO.	ITEMS	UNIT PRICE (RM)	TOTAL PRICE (RM)
1.	Bearing	15.00 X 2 (GST 1.80)	31.80
2.	High Quality Horizontal Shaft Support Linear- Shaft Rail Support CNC Parts Shf16	14.17 X 4	56.68
3.	Flexible Coupling Shaft Coupling Motor Coupler-Connector Aluminum Alloy 8*8mm	10.40	10.40
4.	Sr Paint Mini 75ml	6.00 X 2	12.00
5.	Sr Paint Mini 250ml	5.00 X 2	10.00
6.	Inverter	89.90	89.90
7.	Stainless Steel Shaft 1 Meter	274.00	274.00
8.	PVC Pipe 4 Meter	294.00	294.00
9.	PVC Lid	16.29 X 4	65.19
10.	Generator	160.00	160.00
11.	Step Up Power Module	34.00	34.00
12.	Battery 12v	79.00	79.00
13.	Caster Wheel	32.00 X 4	128.00
14.	Hinge	2.50 X 4	10.00
15.	Others	200.00	200.00
	Items	TOTAL	1454.97