MICRO HYDRO GENERATOR

By

TEH CHOON YAN

DISSERTATION REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
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May 2011

CERTIFICATION OF ORIGINALITY

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

Teh Choon Yan

ABSTRACT

There is a high demand of water usage in Malaysia due to the high population. There is 16,283 million litres of water is used every day. This large amount of water can be fully utilized to produce electricity. Besides that, electricity demand for the residential sector also experience strong growth of 4.9 percent per year due to improving living standards. When the user turns on the tap, there is water flow inside the domestic pipeline and hence produce kinetic energy. Therefore, the aim of this project is to generate electricity through pipeline in the household using micro hydro generator. The flow of water is able to turn the turbine. The turbine is attached to the generator whereby electricity will be generated. Besides that, the choosing of turbine and generator are very important in determining the performance of the project. Hence, feasibility study of Malaysia water system is conducted to obtain the data such as flow rate, water consumption and pressure head. The data obtained will be used to determine how much energy is actually converted and at the same time determine the size of generator needed. Several experimental testing is conducted which are electric circuit testing, open circuit test, turbine test and system test. A prototype of the micro hydro generator is been developed and it is able to generate electricity using the flow of water in domestic pipeline.

ACKNOWLEDGEMENTS

First and foremost, I would like to state my heartiest and sincerest gratitude to my supervisor, Dr Taib bin Ibrahim for his advice and supervision throughout the progress of the research. His useful advice and guidance were like beacons of light, keeping me on the right track in achieving the objectives of this project.

I would also like to dedicate this appreciation to all the technical staffs within Electrical and Electronics Engineering Department especially Ms Siti Hawa. Besides, I would like to thank to technical stuffs from Mechanical Engineering Department for their guidance and valuable suggestions in fabricating the prototype. Besides, En. Shahrul from RIO department does help me a lot in giving me ideas and guidance. I am also deeply grateful to a number of people for their guidance, cooperation and knowledge in easing my learning process.

Last but not least, I would like to dedicate thousands appreciation to my beloved family respectively, dearly my friends and also to those who were involved directly or indirectly in guiding me throughout the whole project development and completing this report.

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LIST OF ABBREVIATIONS

GWh	Gigawatt Hour
DC	Direct Current
AC	Alternating Current
PM	Permanent magnet
PMDC	Permanent magnet DC
Rpm	Rotational per minutes

CHAPTER 1
INTRODUCTION

1.1 Background of Study

Water in Malaysia is mainly supplied to industrial and domestic. Water flow to the domestic would be used as drinking water, watering plants, bathing, cooking and sanitation. Water is not only important as a drinking water but it helps and brings so much convenient to the activities in our daily life. At a turn of a tap, running water is flowing to the consumers from the pipeline. There are a lot of energy could be harvest from the water in the pipeline. Running water in the pipeline is able to generate electricity. The water can be actually fully utilized to produce electricity through a simple conversion of mechanical power to electrical power.

Micro hydro generator will be installed at the domestic pipelines to produce electricity from mechanical power to electrical power. Micro hydro generator is the production of electrical power through the use of the gravitational force of falling or flowing water. For this project, a small turbine will be coupled with a generator inside the pipeline. The turbine will start to rotate when the consumers turn on the tap. The shaft of the turbine rotates in unison with a series of magnet inside the generator. The large magnets rotate past copper coils which will produce voltage and current. This electricity is then passed to the battery charger to store the power in a rechargeable battery as an alternative power supply.

The power generated from the pipeline is depends on the water flow rate, water consumption and pressure head. Pressure head is referred to the height between water intake and the turbine. The flow rate of the water depends on the head pressure from the reservoir and water consumption depends on the amount of water consumed by the consumer every day. The higher of the water flow rate and water consumption, the higher power can be generated.

Besides that, the choosing of turbine and generator are very important in determining the performance of the Micro Hydro Generator. However, the turbines in the market are in bigger in sizes which are applied to the bigger project or water plant. So, it is not suitable to be applied in the domestic pipeline. Hence, the turbine is designed according to the need and requirement of the project. Permanent magnet DC motor is used as the generator of the project due suitability and the good performance of the motor.

1.2 Problem Statement

There is high demand of water usage in Malaysia. From the National Water Resources Study, domestic and industrial water demand for Peninsular Malaysia will increase 3 fold from 9,543 million litres per day (MLD) in 2000 to 31,628 MLD in 2050 [1]. By 2020, it is expected to increase by 2 fold. The present total treatment plant capacity in the country is 16,283 MLD. The water consumption in Malaysia with high population is extremely high. This large amount of water can be fully utilized to produce renewable energy.

On the other side, the growth of electrical demand in Malaysia is strongly increased especially in industrial sector. Total electricity consumption is about 66,450 GWh [2]. Electricity demand for the residential sector also experience strong growth of 4.9 percent per year due to improving living standards [3].

In addition, the usage of water in UTP is enormous due to activities such as watering plants, drinking, bathing, cooking, sanitation and environmental usage such as artificial wetlands in UTP. UTP is currently paying an average RM142, 171 .63 which is equivalent to 113, 2490.32 gallons of water per month. Figure 1 shows the amount paid by UTP for water in four years.

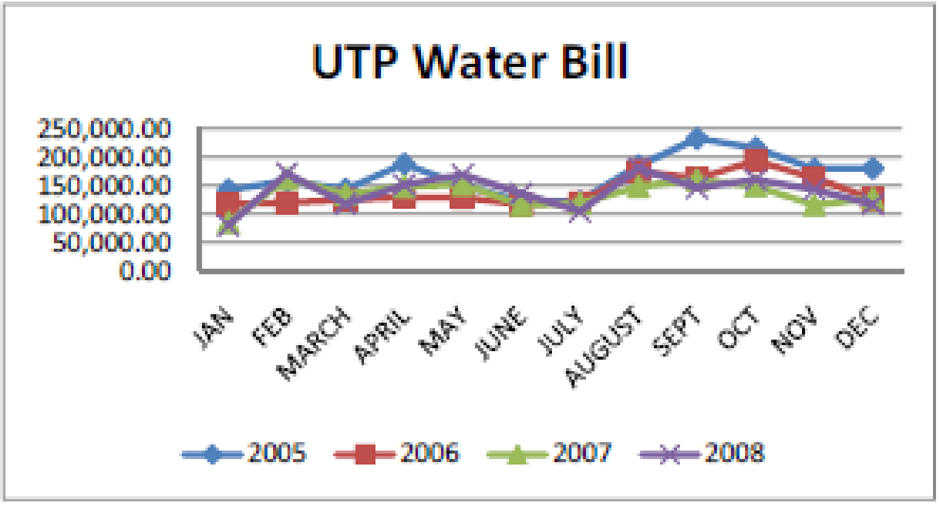


Figure 1 UTP water bill

Hence, generation of electricity play a major role in meeting energy demand needs and combating global warming. Here come out with the idea of design Micro Hydro Generator. The water flow is able to convert the mechanical power to electrical power by installed a micro hydro generator at the domestic pipeline.

1.3 Objective

The main objectives for my project are:

1. Feasibility study of hydro generator in domestic pipeline
2. To design a prototype of micro hydro generator system for domestic pipeline.
3. To test and analyze the prototype of micro hydro generator system.
4. To design electric circuit for power generation storage.

CHAPTER 2
LITERATURE REVIEW

Design a micro hydro system is basically based on the concept use in dam system. The technology used in dam system in generating hydroelectric will be included. Micro hydro generator helps in generating power from the water consumption in domestic pipeline. Hence, survey on the water resources and energy and power sectors are conducted. Theory studies and analyzes which help in selection of DC generator and design of turbine will be stated. Furthermore, how the water flow rate and pressure head effect the power generation is stated as well.

2.1 Previous Design and Technology

Hydropower is one of the oldest sources of energy and has been used for thousands of years. Water Wheels and mills were found in most of the early cultures. Water wheels were mostly used to grind grains in ancient India and water powered mills was also used to saw timber and stone in Imperial Rome. Today, hydropower is considered as renewable energy and is used to produce electricity. In the United States, hydroelectricity power accounts for 6 percent of the total electricity generation [4].

A typical hydropower system consists of dam, reservoir, penstocks, a powerhouse and an electrical power substation. The dam wills stores water and create the head, penstocks will carry water from the reservoir to turbines inside the powerhouse, and the water will then rotates the turbines which drive generator that produce electricity [5] as shows in Figure 2.

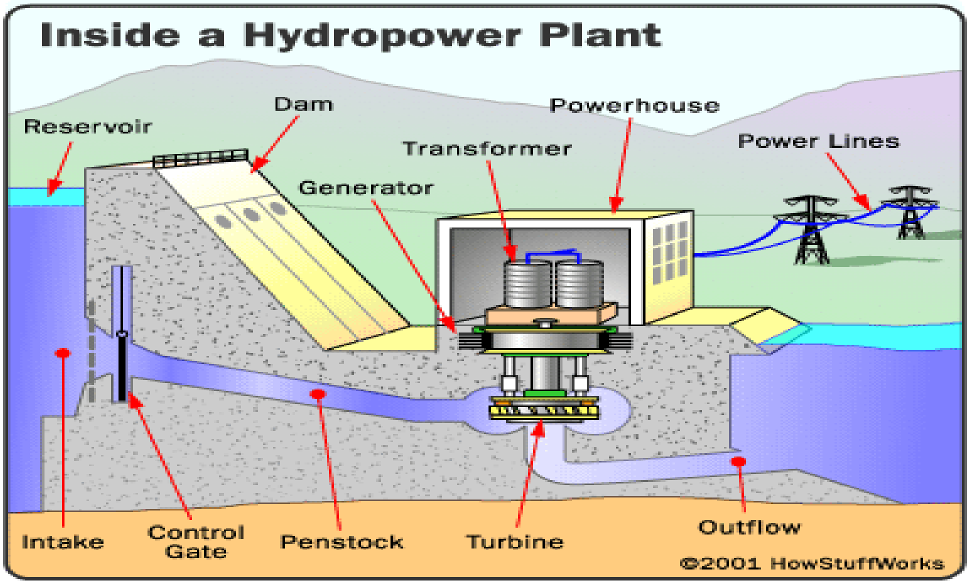


Figure 2 Hydroelectric Dam [6]

There are two main types of hydropower systems which are the conventional type and pumped storage type. Conventional hydropower system is divided into two categories which are run-of-river in Figure 4 and storage plants in Figure 5.

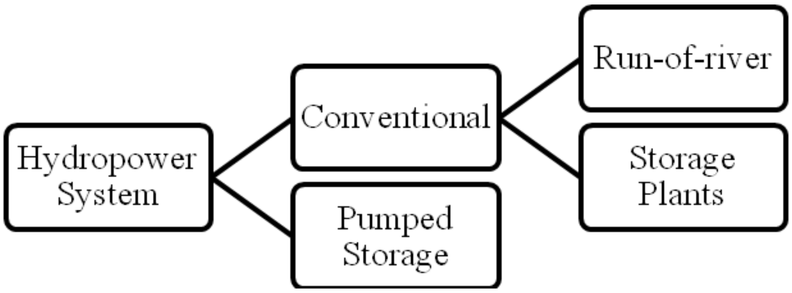


Figure 3 Type of hydropower system

Most hydropower plants are conventional in design where they use one-way flow to generate electricity. Run of river classified as a type of hydro generation use the natural downward flow of rivers and micro turbine generators to capture the kinetic energy carried by water. Typically water is taken from the river at a high point and gravity fed down a pipe to a lower point where it emerges through a turbine generator and re-enters the river.

Installation of such a system is relatively cheap and has very little environmental impact.

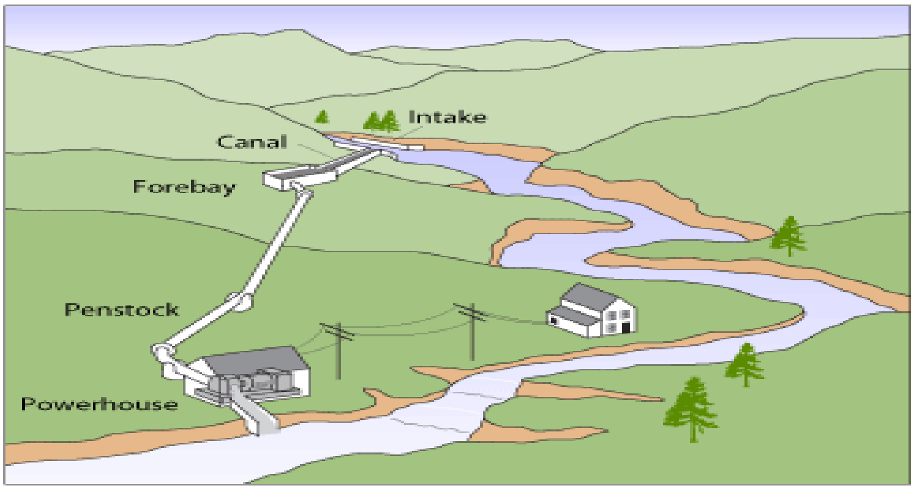


Figure 4 Run-of-river [7]

Storage plant store the water on the upper part of the reservoir as shown in Figure 5. The water will then flow through the turbine generator, exits and is then carried down to the stream. This type of hydropower system applied a one way water flow to the plant.

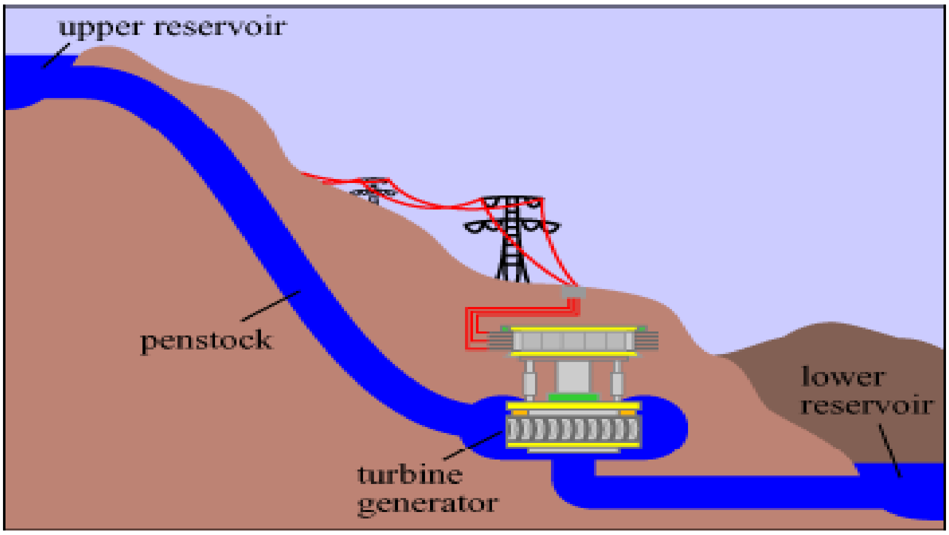


Figure 5 Storage Plants [8]

In contrast to conventional system, pumped storage systems reuse water. The method stores energy in the form of water, pumped from a lower elevation reservoir to a higher elevation. The water will flows from the turbine into a lower reservoir which situated below the dam after the water produces electricity. During the periods of low energy demand, the water will be pumped into an upper reservoir and reused during the periods of peak demand [6].Figure 6 shows the model of pumped storage system:

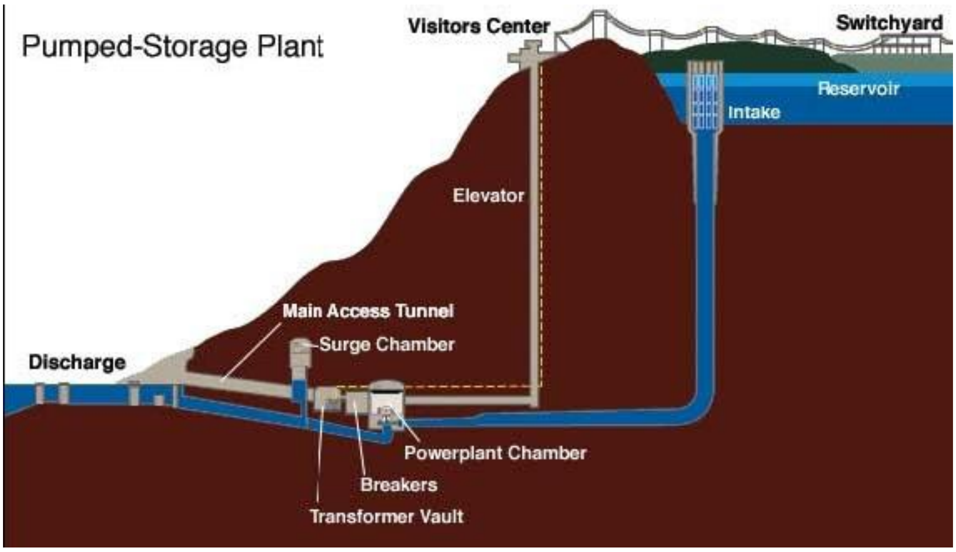


Figure 6 Pumped Storage System [5]

2.2 DC Generator

DC generators are dc machine used as generators. A DC motor can be used as DC generator and vice versa. There is no real difference between a generator and a motor except for the direction of power flow. All generators are driven by source of mechanical power, which usually called the prime mover of the generator. For this project, prime mover is the water flow from the pipeline. The energy conversion in generator is based on the principle of the production of dynamically induced e.m.f. whenever a conductor cuts magnetic flux, dynamically induced e.m.f is produced in it according to Faraday's Laws of Electromagnetic induction. This e.m.f causes a current to flow if the conductor circuit is closed. Hence, two basic essential parts of an electrical generator are magnetic field and conductor which can so move as to cut the flux [9].

In this project, permanent magnet (PM) motor is chosen as the DC generator due to its suitability to the project. There are four types of PM motor, classified according to the manner in which their field flux is produced and this will affect the generator overall's performance in generating voltages and currents. Below shows the types of permanent magnet motor:

1. Permanent Magnet DC Motor (PMDC)
2. Permanent-magnet Brushless Synchronous Motor
3. Permanent Magnet Stepper Motor

The reasons of choosing permanent magnet motor as the project's generator in term of the features and the characteristics of the motor will be stated at below.

2.2.1 Permanent Magnet DC Motor

A permanent magnet DC (PMDC) motor is a DC motor whose poles are made of permanent magnets. PMDC motors offer a number of benefits compared with shunt DC motors as below [10]:

- No electrical energy is absorbed by the field excitation system and this there are no excitation losses which means substantial increase in the efficiency.
- Higher torque and output power per volume than when using electromagnetic excitation.
- Better dynamic performance than motors with electromagnetic excitation (higher magnetic flux density in the air gap).
- Simplification of construction and maintenance.
- Reduction of prices for some types of machines.

PMDC motors do not require an external field circuit, they do not have the field circuit copper losses associated with shunt DC motor. Besides that, since no field windings are required for PMDC motors, they can be smaller than corresponding shunt DC motors. PMDC motors are especially common in smaller fractional and sub fractional horsepower sizes, where the expense and space of a separate field circuit cannot be justified. [11] Micro hydro generator will be installed at the domestic pipeline, hence, a smaller size and lighter motor is perfectly suit for this project.

2.2.2 Characteristic of Permanent Magnet Motor

The speed of a DC machine operated as a generator is determined by the prime mover. In this project, the prime mover is the water flowed from the pipeline and the generator is connected to the turbine so that the load of the generator is constant. Under such condition, the generator performance deals primarily with the relation between terminal voltage and current and the speed of generator. These relations can be best exhibited graphically by means of curves known as generator characteristics. These characteristics show at a glance the behaviour of the generator under different speed conditions. Different types of PM motors having different manner of characteristic.

Open Circuit Characteristic (O.C.C.) shows the relation between the generated voltage at no-load and the field current at different speed of generator. It is also known as magnetic characteristic or no-load saturation curve. Its shape is practically the same for all generators whether separately or self-excited. The data for O.C.C. curve are obtained experimentally by operating the generator at no load and recording the change in terminal voltage and field current as the speed of generator is varied [12].

External characteristic (V/I_L) shows the relation between the terminal voltage and load current to the speed of prime mover. The terminal voltage will be lesser due to voltage drop in the armature circuit. Therefore, this curve will lie below the open circuit characteristic. This characteristic is very important in determining the suitability of a generator for a given purpose. It can be obtained by making simultaneous measurements of terminal voltage and load current (with voltmeter and ammeter) of a loaded generator [12].

2.3 Water Turbine

Turbine is one of the main parts of Micro Hydro Generator. When water passes through the turbine, the rotation of turbine is producing mechanical energy. Turbine is fixed on a shaft, and the rotational motion of the turbine is transmitted by the shaft to a generator [13].

In Malaysia, the sources of raw water plant are obtained from the River Silver, which is located near the plant. Water from the river is pumped using four pumps submarine, each with a capacity of 1.110 m3 per hour. Before supply to the consumer, water will undergo several treatment processes such as screening, ventilation, coagulation, sedimentation, filtrations, chlorination, pH adjustment, fluoridation, water quality monitoring and last will distribute to the consumer. Figure 7 below show the detail of water treatment plan.

Figure 7   Water Treatment Plan [14]

Considering the water will be distributed as drinking water, hence, installation of Micro Hydro Generator on existing drinking water systems must be harmlessness to the user. Water contamination must be avoided and at the same time without disturbance to the waterworks supply.

In choosing the turbine of Micro Hydro Generator, the turbine must be moved by electrical motor and no hydraulic regulation is required. So, no oil leakage into the drinking water is possible. Besides, make sure the turbine would not rusty [15]. It would be an advantage if the turbine has patented sealing system of the bearings and even uses biological grease for lubrication.

2.3.1 *Classification of Turbines*

Water turbine for small, mini and micro power plants are classified as below:

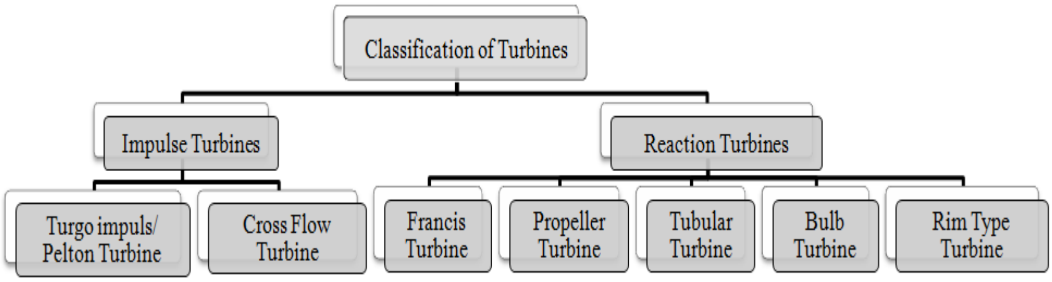


Figure 8 Classification of Turbines [16]

Turbine selection is based mostly on the available water head and flow rate. In general, impulse turbines are used for high head sites, and reaction turbines are used for low head sites. From Figure 9, Kaplan turbines are well-adapted to wide ranges of flow or head conditions due to their peak efficiency can be achieved over a wide range of flow conditions.

Small turbines (mostly below 10 MW) may have horizontal shafts and even fairly large bulb-type turbines up to 100 MW or so may be horizontal. Very large Francis and Kaplan machines usually have vertical shafts because this makes best use of the available head, and makes installation of a generator more economical. Pelton wheels may be either vertical or horizontal shaft machines because the size of the machine is so much less than the available head. Some impulse turbines use multiple water jets per rotation to increase specific speed and balance shaft thrust.

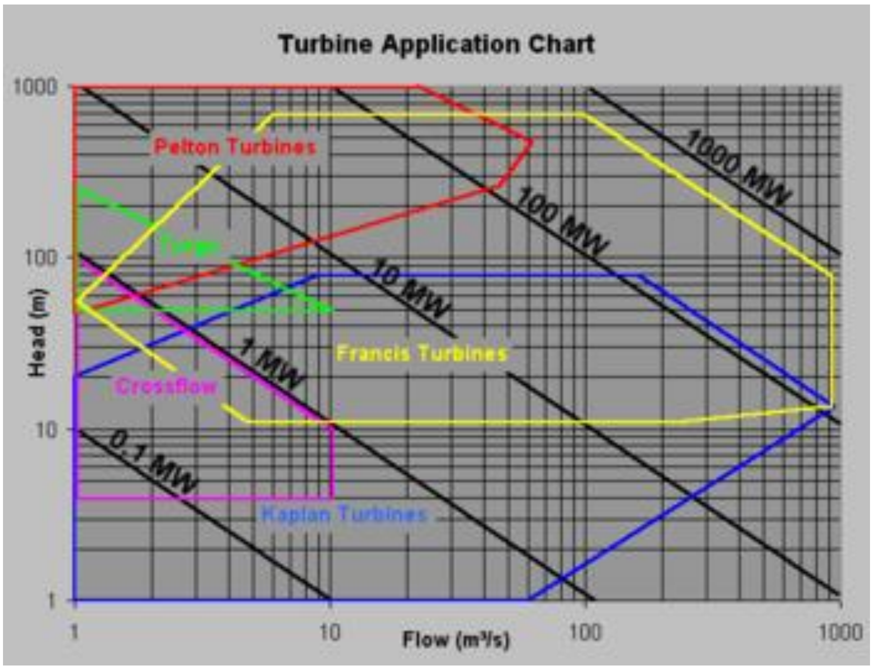


Figure 9 Turbine Application Chart [17]

2.4 Head and Flow Rate

Generated power is proportional to the flow rate and pressure head of water. The higher the flow rate and pressure head of water are able to produce higher level of kinetic energy which will turn the runner blades of the turbine and start rotating. The generator’s shaft coupled to the turbine start to move and hence convert the kinetic energy to electrical energy.

Gross head is the vertical distance between the penstock and where the water leaves the turbine. Penstock is where the pipe takes water from the stream. In determining the head, gross and net head are two types of head to be considered. Net head is the gross head minus pressure losses due to friction and turbulence. Minimizing the length of the pipeline and turns in the pipeline can prevent some losses to pressure [18].

However, all the water supply to the housing area will go through PRV (pressure reducing valve) before send to the user. Hence, the pressure head from the meter point (direct) is range from 80-130ft for the whole Malaysia.

Water flow rate is the water quantity or volume which passes through a given surface per unit time. It can be determined by using the formula as below:

$$Q = A.V\ [m^3/s]$$

Where,

A=Area
V= Velocity

Besides that, the higher water consumption would increase the amount of power generated. This due to the period of time for the project to generate electricity is longer. According to HJ. Shapiei bin HJ. Mustapa (Manager of Perak water resources), water resources in Perak is divided into ten districts which are Kinta area, Perak Tengah, Manjung, Batang Padang, Hilir Perak, Larut Matang and Selama, Kerian, Kuala Kangsar, Hulu Perak and Kampar. According to him, the domestic water consumption is range from $0.8m^3 - 1.2m^3$ per day.

2.5 Gear Wheel

Gear is a toothed wheel that engages another toothed mechanism in order to change the speed or direction of transmitted motion from one rotating shaft to another. The motion of the motor must be transmitted to the shafts carrying the rollers. In addition to transmitting the motion heats ate often used to increase or reduce speed, or change the direction of motion from one shaft to the other.

Considering the function of gear wheel, turbine speed can be increased by connecting the shaft of the turbine to the geared devices. When the speed is increased, the mechanical power transmitted to the generator will increase as well. The higher the mechanical power to the generator, the higher will be the electrical power generated.

2.5.1 Type of Gear

There is various type of gear. Each type of gear has its own purpose as well as unique advantages and disadvantages. Spur gears are simplest and the most common type of gear. The teeth of a spur gear are parallel which encompass the majority of applications. A pair of spur gears is illustrated in Figure 10(a).

Besides spur gears, a rack is a special case of spur gear where the teeth of the rack are not formed around a circle but it laid flat. The rack can be perceived as a spur gear with an infinitely large diameter. When the rack mates with a spur gear, translating motion is produces. A mating rack gear is shown in Figure 10(b).

Internal gears have the teeth formed on the inner surface of a circle. When mating with a spur gear, the internal gear has the advantage of reducing the distance between the gear centers for a given speed variation. An internal gear mating with a traditional spur gear is shown in Figure 10(c).

Helical gears are similar to spur gears. The difference is that the teeth of a helical gear are inclined to the axis of rotation. Helix angle provides a more gradual engagement of the teeth during meshing and produces less impact and noise. Helical gears are preferred in high-speed applications because of this smoother action. However, the helix angle produces thrust forces and bending couples, which are not generated in spur gears. A pair of matching helical gear is shown in Figure 10(d).

Herringbone gears are used in the same application as spur gears and helical gears. In fact, they are also referred to as double helical gears. The herringbone gear appears as two opposite-hand helical gears butted against each other. This complex configuration counterbalances the thrust force of a helical gear. A herringbone gear is shown in Figure 10(e).

Bevel gears have teeth formed on a conical surface and are used to transmit motion between nonparallel shafts. Bevel gears are designed as asset, and replacing one gear to alter the gear ratio is not possible. A pair of mating bevel gears is shown in Figure 10(f).

Miter gears are a special case of bevel gears where the gears equal size and the shaft angle is 90°. A pair of mating miter gears is shown in Figure 10(g). Last, worm gear is used to transmit motion between nonparallel and nonintersecting shafts. The worm has one tooth that is formed in a spiral around a pitch cylinder. Similar to the helical gear, the spiral pitch of the worm generates an axial force that must be supported. In most applications, the worm drives the worm gear to produce great speed reductions. A mating worm gear is shown in Figure 10(h) [19].

(a) Spur Gear

(b) Rack and Pinion

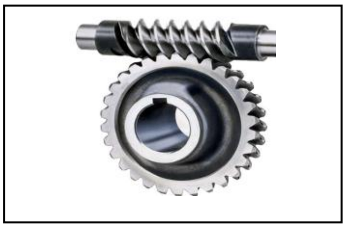
(c) Internal Gear

(d) Helical Gear

(e) Herringbone Gear

(f) Bevel Gear

(g) Miter Gear



(h) Worm Gear

Figure 10 Gear Types

2.5.2 Gear Ratio

A gear ratio defines the relationship between multiple gears. On any gear, the ratio is determined by the distances from the center of the gear to the point of contact. Gear ratio also can be defined as:

$$\text{Gear Ratio} = \frac{\text{Teeth output gear}}{\text{Teeth input gear}}$$

Torque is a force that tends to cause a rotation. It is product of force and distances. Gear ratio is proportional to the torque while it is inversely proportional to the speed. When the speed is increased, the torque will reduce.

To increase speed and reduce torque, use a large drive gear coupled to a smaller driven gear. Hence, gear ratio will be smaller than one. Inversely, to decrease speed and increase torque, use a smaller gear coupled to a larger driven gear. So, gear ratio will be greater than one.

2.6 Current Booster

Current booster circuit is a module named (EH300A) that used to boost up the generated current by continuously and actively operate to capture, accumulate and conserve energy from the generated power. This module is able to accept input voltages ranging from 0.0V to +/- 500V AC or DC, and input currents from 200nA to 400mA from energy harvesting sources that produce electrical energy.

For this module, the voltage on the onboard storage capacitor bank is +V, which is also the positive supply voltage switched to power the output power load. Initially, +V voltage start at 0.0V. During the initial charge period, +V starts charging from 0.0V. The internal circuit of the Module monitors and detects this +V voltage. When +V reaches V_H, the Module output (V_P) is enabled and turned to the ON state and is then able to supply power to a power load, such as a microprocessor or a sensor circuit. The amount of useful energy available is a function of the capacity of the storage capacitor bank.

Meanwhile, this module continues to accumulate any energy generated by external energy sources. If external energy input availability is high, output V_P remains in an ON state continuously, and until such time that external energy availability is lower than the power demand required by the power load. As external energy input exceeds power loading, +V increases until internal voltage clamp circuits limit it to a maximum clamp voltage.

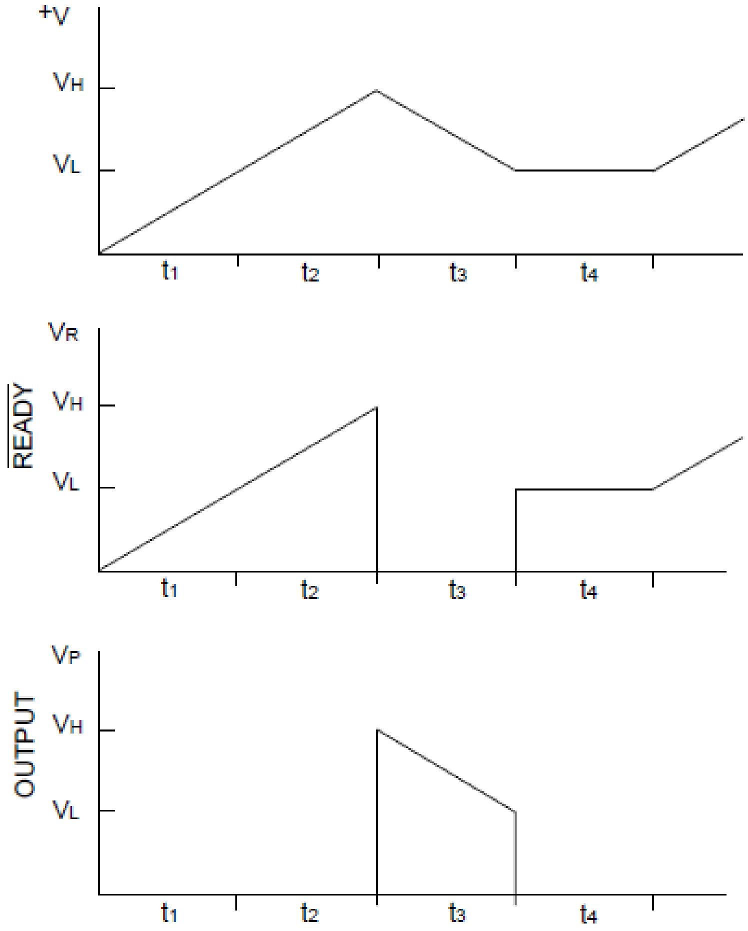


Figure 11 Performance of EH300A [20]

During normal operation, as power is drawn from the module, +V decreases in voltage. When +V reaches V_L, output V_P switches to an OFF state and stops supplying any further power to the power load. With built-in hysteresis circuits within the module, V_P now remains in the OFF state even when the external energy source starts charging the capacitor bank again by importing fresh new impulses of electrical energy. Once V_H level is reached again, output V_P is then turned to the ON state again. When in the ON state, V_P can supply up to 1A of current for a limited time period as determined by the stored useful energy and the energy demand by the power load. Input energy charging times t1 and t2 are limited by input energy available minus energy loss. The energy output time period t3 is determined by the rate of energy used by the power load as a function of energy stored. Low input energy hold time t4 is typically many orders of magnitude greater than the sum of t1, t2 and t3.

2.7 Voltage Booster

Booster circuit used to boost up the input voltage to produce a higher output voltage and current. This circuit is able to store the input energy temporarily and then releasing that energy to the output at a higher voltage and current. The main part of this circuit is MAX1724. This is a boost converter IC that can easily be configured as a step-up or step-down converter.

The maximum generated voltage is 6.65V. However the water flow in the domestic pipeline is not constant all the time. In this project, it is basically being used to step up 1.5 V of voltage to achieve 5 V of output. This can make sure that even a minimum voltage is able to charge a hand phone.

When the switch is ON, the diode is reversed biased, thus isolating the output stage. The input supplies energy to the inductor. When the switch is OFF, the output stage receives energy from the inductor as well as from the input. Figure 31 shows the voltage booster circuit.

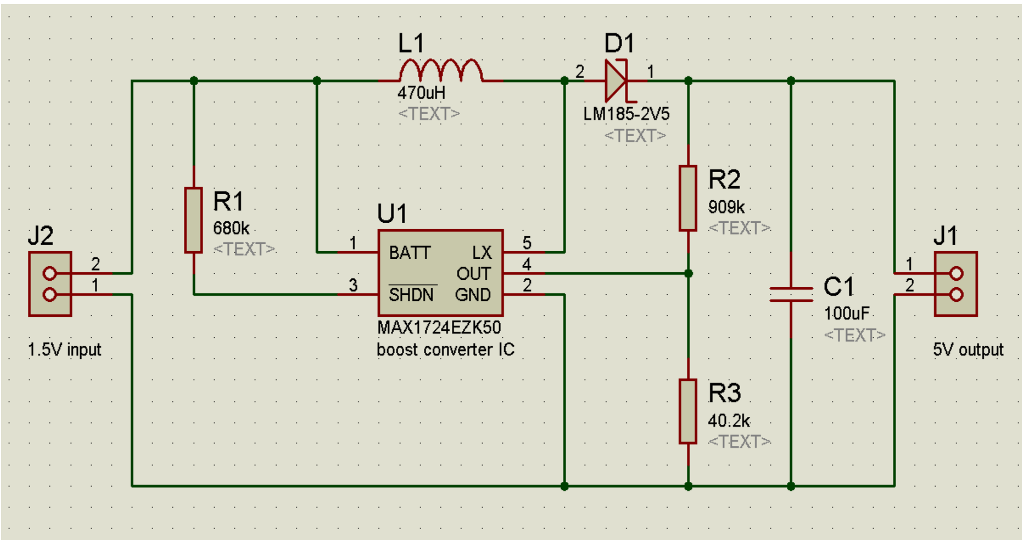


Figure 12 Voltage booster Circuit

2.8 Power Conversion and Efficiency

The electricity is generated from the conversion of one form energy to another. The turbine converts the energy in the moving water into rotational energy as its shaft, which is then converted to electrical energy by generator [21].

The two types of energy involved are kinetic energy and potential energy. Kinetic energy is the energy that an object has because of its motion relative to its surrounding. It has the ability to do work on other object by applying a force to those objects in order to change its velocity [22]. Another types of energy involve is potential energy where potential energy is the energy that is stored in a system by virtue of forces between some distance of objects.

When the object (in this case is the flowing water) move under the influence of the force between the potential energy, then work is done as the force displaces of the objects from their initial positions and thus energy is transferred. The potential energy of a volume of water that falls through of a height is obtained as below [23]:

$$F_{gravity} = (\text{mass})\ (\text{acceleration due to gravity near Earth})$$
$$= (\text{mass})\ (9.80\ \text{m/sec}^2)$$

$$\text{Potential Energy} = (F_{gravity})\ (H)$$
$$= (\text{mass})\ (9.80\ \text{m/sec}^2)\ (H)$$

In a micro hydro system, the mass of the water that is falling is determined by how much volume it occupies where:

$$\text{Mass} = (\text{Density})\ (\text{Volume})$$

Where,

$$\text{Density} = 1\text{gm/cm}^3\ (\text{for fresh water})$$

Thus, potential energy of a volume of water is:

$$\text{Potential Energy} = (98000\text{J/m}^4)\ (\text{VH})$$

Where,

J is the symbol for the unit of energy called the joule.

Amount of power available from the micro hydro system is also directly related to the flow rate, head and the force of gravity.

The electrical power can be calculated using the equation below:

$$P_{theory} = (Q)\ (H)\ (g)$$

Where,

P_{theory} = theoretical power output in kW

Q = Usable flow rate litres/s

H = Gross head in m

G = Gravitational constant (9.81m/s)

During the conversion of one form of energy to another form of energy, some of the energy will be lost through friction at every point of conversion .Efficiency is measurement of how much the energy is actually converted. It is represented as below [23]:

Efficiency = (electrical energy output) / (potential energy)

$$= (\text{electrical energy output}) / ([98000\text{J/m}^4] \text{ X VH}) \qquad [21]$$

Net energy = (Gross energy) (Efficiency) [22]

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

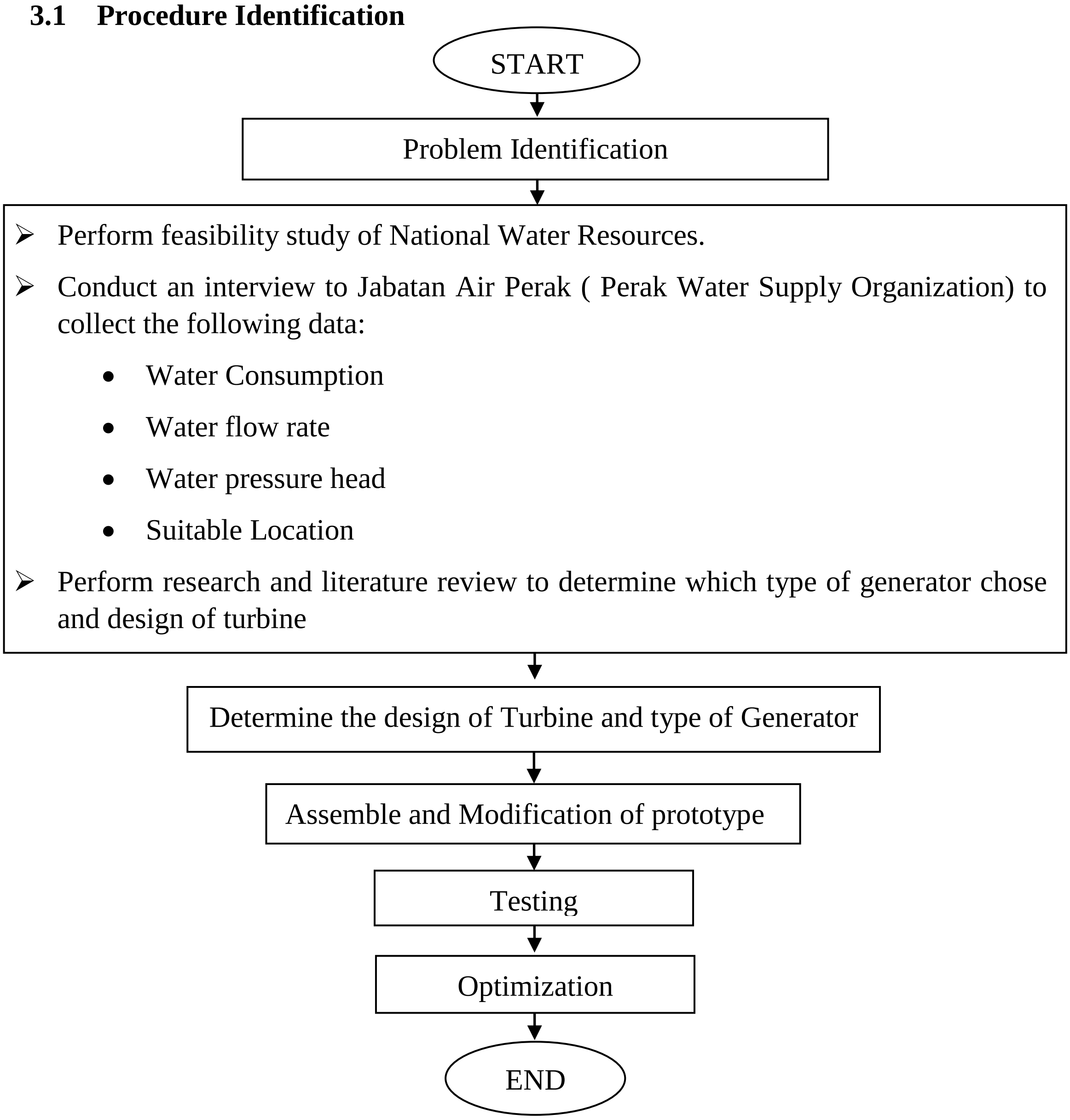


Figure 13 Flow chart of project in Semester I

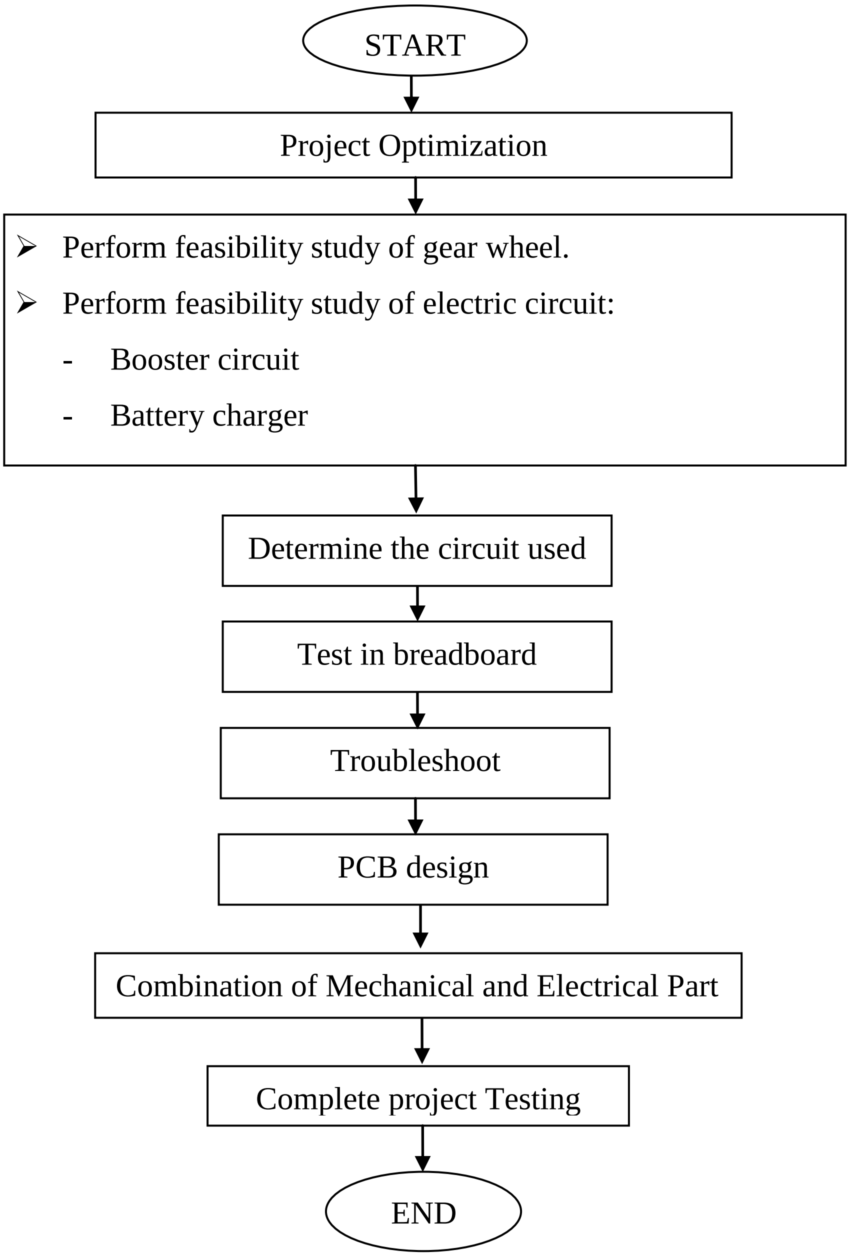


Figure 14 Flow Chart of project in Semester II

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3.2 Research Activities

This project is divided to two main parts:

(i) Mechanical Part

(ii) Electrical Part

Mechanical part is referred to the prototype consists of generator and turbine. This is the main part of the project where it determines the amount of voltage can be generated. For the electrical part, it is an additional part to add the function and improve the efficiency of prototype. Electrical part includes battery charger, rechargeable battery and switching circuit.

3.3 Research and Study

Information regarding the project is gathered from respective books, journals, thesis and internet. All the information are skimmed and selected based on the important and relevancy. The relevant information and example data are studied thoroughly. Research and study is important to have more understanding on the project in determining what material and component and part should be used in the system.

3.4 Tools and Equipment used

Equipments	Materials
Multimeter	Turbine
Tachometer	DC generator
Timer	PVC pipe
Power Supply	Bearing
	O-ring

3.5 Data Gathering

Micro Hydro Generator is aimed to be used in housing area hence all the data regarding to the water and electric consumption is needed. Volume of water used in everyday and the pressure head of water is important in determining the voltage generated. Hence, an interview is held to gather the data of water consumption and pressure head in Malaysia housing area.

3.6 Laboratory Work

For semester I, experimental work is needed to determine the flow rate of water. This is useful to estimate amount of power generation. Besides, open circuit test and system test are used to check the performance of the project.

In semester II, experimental work is needed for further improvement of the project. In mechanical part, gear is added to the prototype to increase the speed of the turbine and hence generate higher power. In parallel to gear installation, circuitry part is needed to store the power generated.

3.6.1 Flow Rate Test

Water flow rate is measured in meter cube per second. It can be determined by measure the flow of water in a period of time. Flow rate can be manually determined by measure the time taken to fill 10 litres of water from domestic pipeline.

3.6.2 Open Circuit Test

Typically a motor takes power in the form of voltage and current and converts the energy into mechanical energy in the form of rotation. With a generator, this process is simply reversed. A generator takes mechanical energy and converts it into both electrical energy with a voltage and current. Most motors can be generators by just spinning the motor and looking for a voltage or current on the motor windings.

When connecting two motors together, if you spin one, the other spins based on the current created when turning the windings of the first motor. The speed of the first motor can be altered by the amount voltage supply. The higher the voltage supply, the higher the speed of the shaft and the greater the mechanical power supply to second motor. Second motor is now become a generator which take in mechanical power and convert to electrical power.

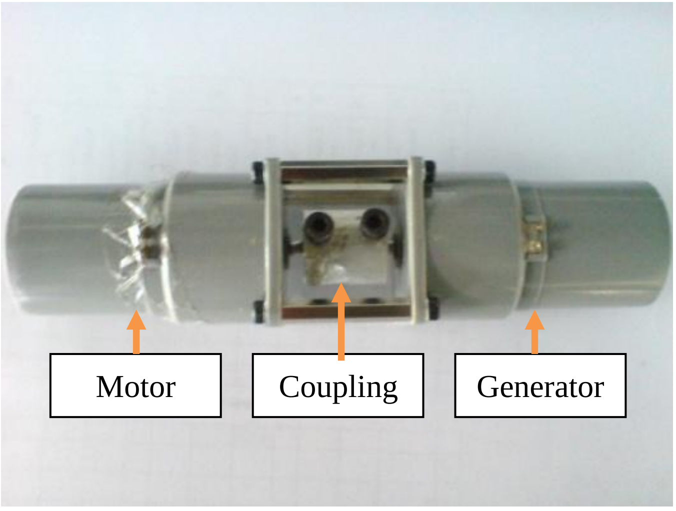


Figure 15 Set Up of Open Circuit Test

To test back EMF of motor with various speed, an experiment connecting two motor is needed. Voltage supplied to the first motor. The speed of the shaft is determined by using tachometer. Vary the voltage supply when the speed of the motor increases every 10rpm. At the same time, voltage and current generated is recorded at the second motor. Figure 15 show the connection of open circuit test.

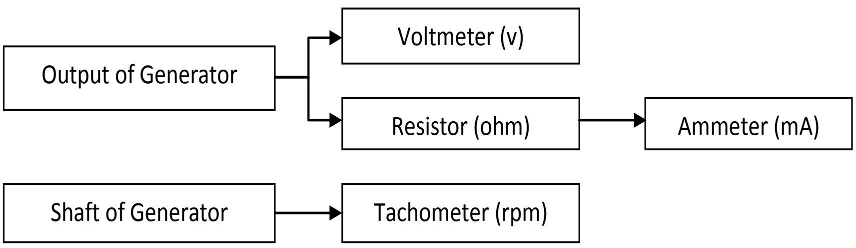


Figure 16 Connection of Open Circuit Test

3.6.3 System Test

Open circuit test is a testing without any loads. Inversely, system test refer to the test after connect the generator to the turbine. Use the flow of water as a prime mover to supply mechanical power to generator. Tachometer is used to record the speed of turbine's spinning and the voltage and current generated are recorded. The connection for this test can be referred to Figure 16.

Figure 17 Set up for system test

3.6.4 Electric Circuit

Micro hydro generator is able to generate 6.65V and 17.33mA. The voltage generated is good enough in many applications for example as lighting system or even use to charge a hand phone battery.

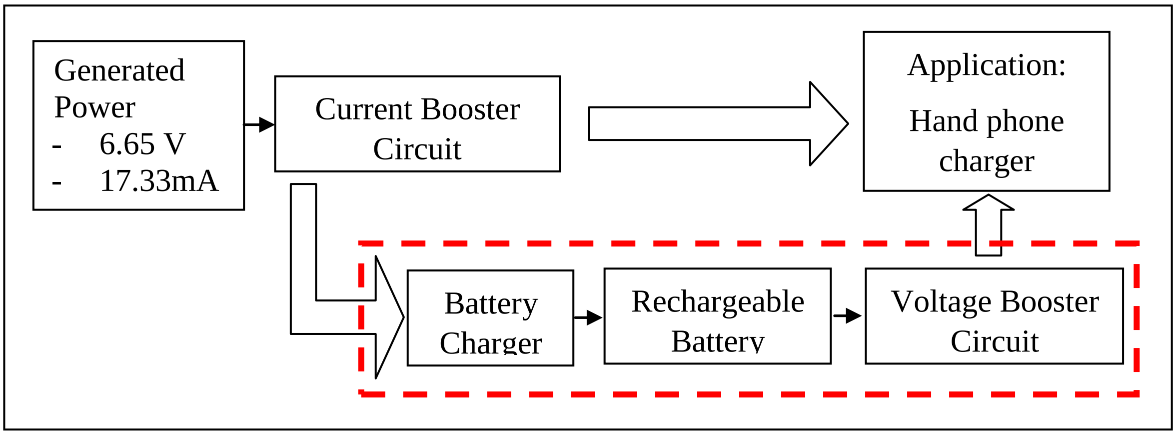


Figure 18 Connection of circuitry part

However, to charge a hand phone battery, approximately 150mA is needed to charge a hand phone. The current generated is only 17.33mA and it would take few days to charge a hand phone battery. Hence, a current booster circuit is needed by connecting to the output of generator to boost up the current. Boosted output can used to charge the hand phone battery and store the generated power into rechargeable battery.

The generated power from the booster circuit can be stored in a rechargeable battery by using battery charger. The rechargeable battery is an AA battery, 1600mAh. The output of the battery is only 1.5V. Hence, voltage booster is needed to boost up the voltage to charge the hand phone battery.

The red doted part will be installed in a small box. Once the rechargeable battery is full, this small box can be removed from the prototype to be a portable hand phone charger. The advantage is we are able to charge our hand phone everywhere, anytime.

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Data Gathering

An interview had been conducted to Jabatan Air Perak to get some information on the pressure head and water consumption. According to HJ. Shapiei bin HJ. Mustapa (Manager of Perak water resources), domestic water consumption is range from $0.8\text{m}^3 - 1.2\text{m}^3$ per day [24].

In term of pressure, all the water supply to the housing area will go through PRV (pressure reducing valve) before send to the user. Hence, the pressure head from the meter point (direct) is range from 80-130ft for the whole Malaysia.

4.2 Prototype Construction

Turbine and generator are the two main parts in prototype construction. The performance of the project are mainly depends on the turbine and generator used in the project. Hence, some discussion and decision making on the turbine and generator are included in the following parts.

4.2.1 Design of Turbine

Water turbine for this project is designed instead of selecting a complete turbine sold in the market. From the classification of turbine at Part 2.3.1, all the turbines are designed in bigger sizes which are not suitable to be installed into domestic pipeline. Referring to the design of turbine in the market, some ideas and criteria of designing a turbine is used in designing a new turbine which is specialist applied to Micro Hydro Generator. The design of blade and shaft and the usage of o-ring and bearing will be specified as below.

The blade of the turbine had been made curve in order to decrease friction to the water flow. Besides that, the curve also important in order to catch more water as the water flow through the turbine in order to increase the torque to rotate the turbine. Therefore, it will increase the rotational per minutes of the turbine.

Figure 19 Curve shape turbine

The usage of O-ring is important in order to avoid leakage. The O-ring is functioning using the application of water pressure, where as the turbine is rotating, the pressure from the water will push the O-ring to the surface of the casing therefore it will block the water from flowing through the shaft to outside casing.

Besides that, bearing is used in order to ensure that the rotation of the turbine is smooth and also decrease the friction between the shaft and the Perspex. Therefore, it could increase the rotational per minutes of the turbine. It is also could stabilize the turbine.

The shaft is connected in between the turbine and the motor. There is a hole at the shaft where we could join the shaft of the turbine with the shaft of the motor. Hence, the kinetic energy from the shaft will be converting into electrical energy by the motor.

Figure 20 Shaft connected to O-ring and Bearing

4.2.2 Proposed PMDC motors as DC Generator

There are four types of PMDC motors from Philips Manufacturer. This range of small DC motors with integrated gear train is designed for applications requiring quality design and long life drive units. Spark suppression is obtained by a sandwich mounted dics-VDR between commutator and rotor coils. The grey injected plastic housing is highly resistant to chemicals and corrosion. Figure 21 is one of PMDC motors.

Figure 21 PMDC motors manufactured by Philips [25]

4.2.2.1 Typical Performance curves of PMDC motors

Figures below shows the performance for four types of PMDC motors from Philips Manufacturer. The following shows the part numbers for those types of motors which I would like to named it as below:

Motor A: 9904 120 52402

Motor B: 9904 120 52405

Motor C: 9904 120 52602

Motor D: 9904 120 52605

The performance of Motor A and Motor C are stated in Figure 22 and the performance of Motor B and Motor D are stated in Figure 23.

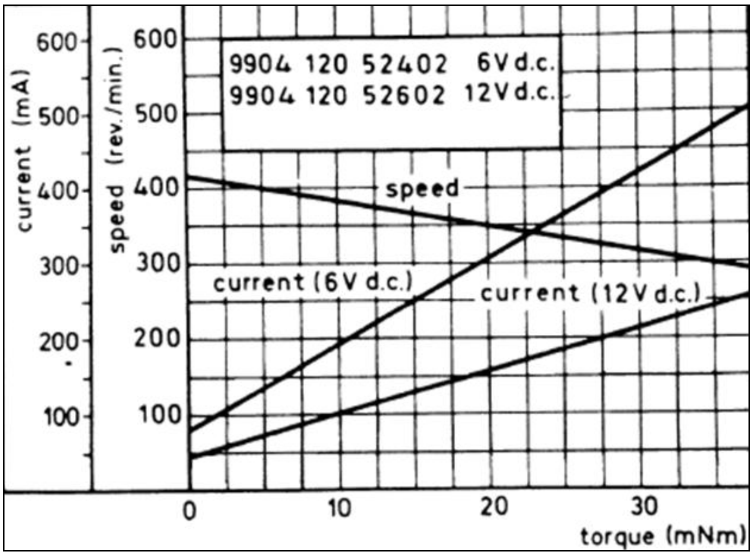


Figure 22 Performance of Motor A and Motor C [25]

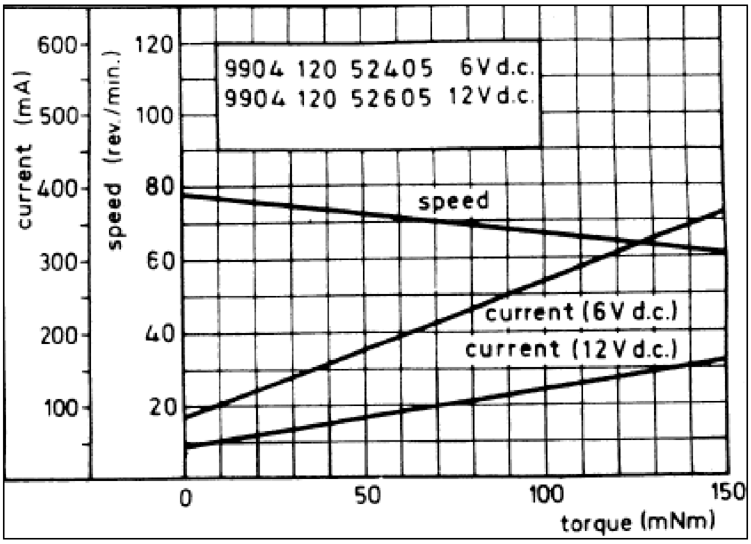


Figure 23 Performance of Motor B and Motor D [26]

From the performance of all motors, Motor C is proposed as the DC generator used in Micro Hydro Generator by considering the speed of motor and the DC voltage supplied to the motors. In Motor C, a lower torque is used to drive a high speed of motor. Besides that, Motor C has the highest DC voltage which is 12 Vdc and it allows the generator to generate voltage up to 12V instead of 6V.

4.2.2.2 Specification and Parameters of Proposed Motor

Specification is very important in providing some information in testing the motor and protects the motor being damaged. The specified rated current values should not be exceeded. Indicated no load currents are maximum values, to be considered as worst case over the whole motor life. In practice, new motor will show significantly lower values. The specification of the proposed motor is as in Table 1.

Table 1 Specification of Proposed DC Generator

Part Number: 9904 120 52602	
Width	39mm
Length	67mm
Shaft Diameter	4mm
Shaft Length	8.55mm
Voltage (dc)	12V
Torque	25mNm
Speed : at nominal load : at no load	330 rpm 415 rpm
Input Power	2.2 W
Direction of Rotation	Clock Wise
Max Voltage (dc)	18V
Max permanent load	37.5mNm

4.3 Experimental Result

For FYP I, there are three main experiments to test the performance of Micro Hydro Generator. There are open circuit test, turbine test and system test. For FYP II, generated power after gear is installed compare to the result of the prototype without gear will be conduct. Besides, circuit testing for power storage in AA battery and a simple application to charge the hand phone will be mentioned in detail on the following topic.

4.3.1 Open Circuit Test

Open circuit test is conducted by coupled two motor together. In Figure 19, it shows the testing for open circuit test. Voltage is supplied to the first motor to supply mechanical power to the second motor which acts as generator in this experiment will convert mechanical power to electrical power. The generated voltage and current are tested using voltmeter and ammeter. The speed is tested using Tachometer as shown in Figure 24.

Figure 24 Testing speed for open circuit test

The speed of the motor can be altered by the amount voltage supply. The higher the voltage supply, the higher the speed of the shaft and the greater the mechanical power supply to the generator. As a result, a higher voltage and current are generated.

While voltage is gradually increased and supplied to the motor, the speed of motor are recorded every 10rpm different. Figure 25 shows the amount of voltage and current generated with different speed of generator. The current and voltage generated are proportional to the speed of generator. The generator does not move until it reaches 50 rpm in this experiment. It is because the motor need a starting torque to start up the motor. After the motor started, only then supply mechanical power to the generator.

Starting Torque is the torque the electrical motor develop when its starts at rest or zero speed. A high Starting Torque is more important for application or machines hard to start. A lower Starting Torque can be accepted in applications as centrifugal fans or pumps where the starts load are low or close to zero [27].

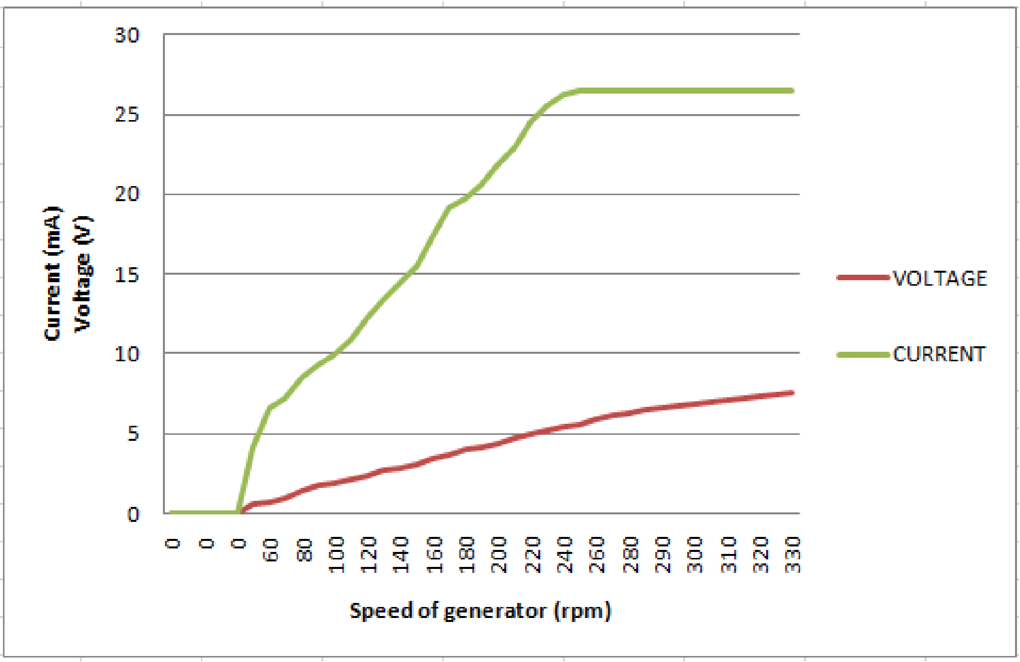


Figure 25 Output Voltage and Current with the changes of generator speed

4.3.2 Turbine Test

Turbine test is conducted to test the speed of turbine using the flow rate of water. When the speed is determined, the voltage and current generated can be estimated by referring the result from Figure 25 in open circuit test.

Figure 26 Turbine test without generator

From the turbine test, the average speed of turbine with the flow of water is 310.2 rpm. From Figure 27, estimation can be made from the result of open circuit test where the generator is able to generate 7V and 26mA.

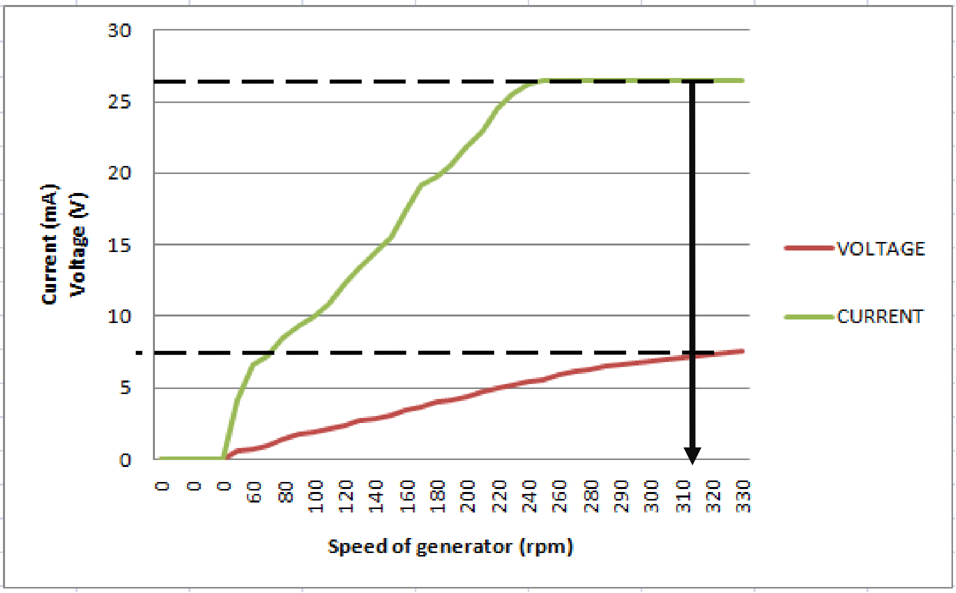


Figure 27 Estimation of power generation from open circuit test's result

4.3.3 System Test

In system test, generator is coupled to the turbine. Throughout the test, water from the domestic pipeline is flow into the prototype. The output voltage and current are tested and the data from the test are recorded in Table 2 and 3. Figure 28 shows picture taken during the test.

Figure 28 Set up for system test

4.3.3.1 Voltage generated

Generated voltage is tested at the output of generator and the speed of generator is tested at the connector connecting the shaft of generator and turbine. Since the readings are varying throughout the test, hence, only the maximum and minimum readings are recorded and stated in Table 2. From the test, generated voltage is increasing with the speed of generator.

The voltage generated varied whenever the speed of generator is changing. The changes of speed might due to the flow rate of water is not constant, the more user using the water at the same time, the lower the pressure the water is and hence the flow rate of water become slower. Although the speed of the generator varying, it manage to maintain the speed in a range of limit.

Table 2 Speed and generated voltage

Speed of generator (rpm)		Generated voltage (V)	
Minimum	Maximum	Minimum	Maximum
220	266.4	6.34	6.953

4.3.3.2 Current generated

Current generated are recorded using ammeter with connecting in series with a resistor. The speed of generator is tested using tachometer. Table 3 shows the data gained.

Table 3 Speed and generated current

Speed of generator (rpm)		Generated current (mA)	
Minimum	Maximum	Minimum	Maximum
127.7	133.8	15.823	18.846

4.3.4 Electrical Circuit

Voltage booster and current booster are shown in figure 30. On the other hand, the complete circuit part as in Figure 32(a) is tested by connecting the power supply to the input of the circuit. The circuit can be tested by varied the voltage and current supply from the power supply, and then check the output voltage and current. The output of the circuit is connected to the hand phone to determine what is the minimum voltage and current input to charge a hand phone. Table 4 shows the result of the circuit testing.

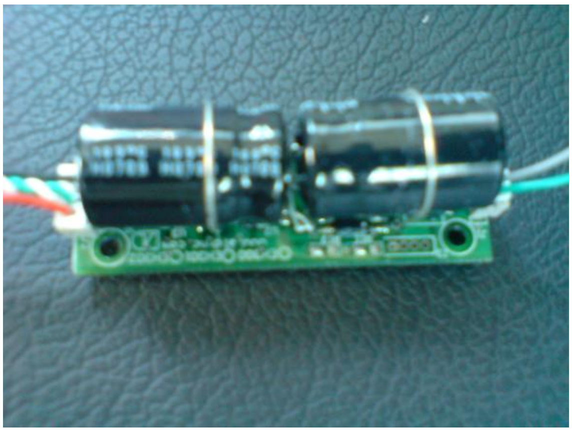


Figure 29 Current booster circuit

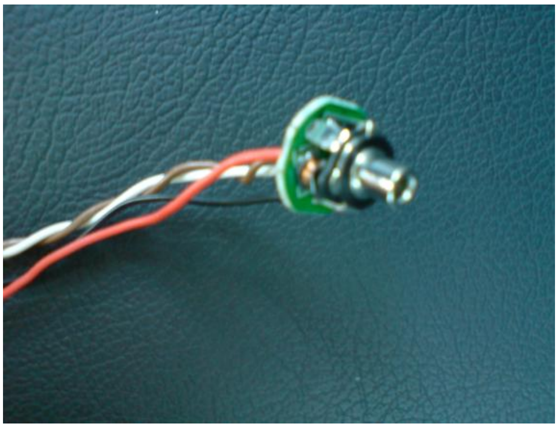
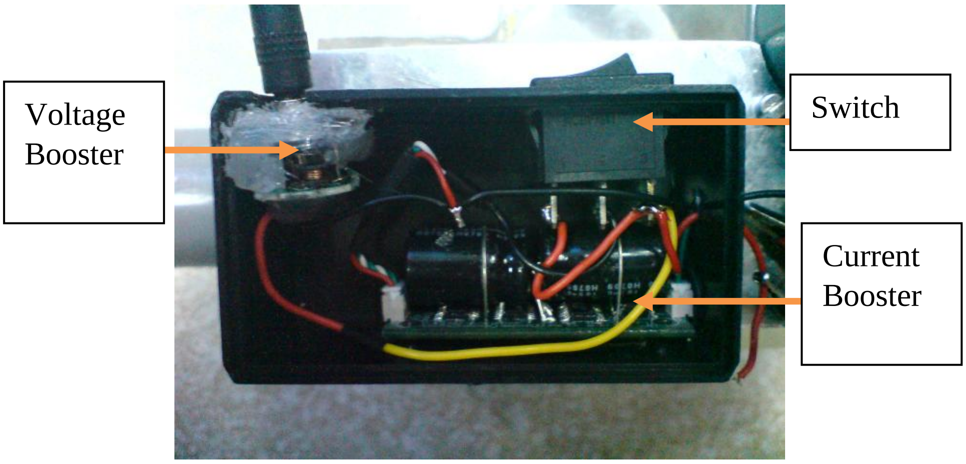


Figure 30 Voltage booster circuit

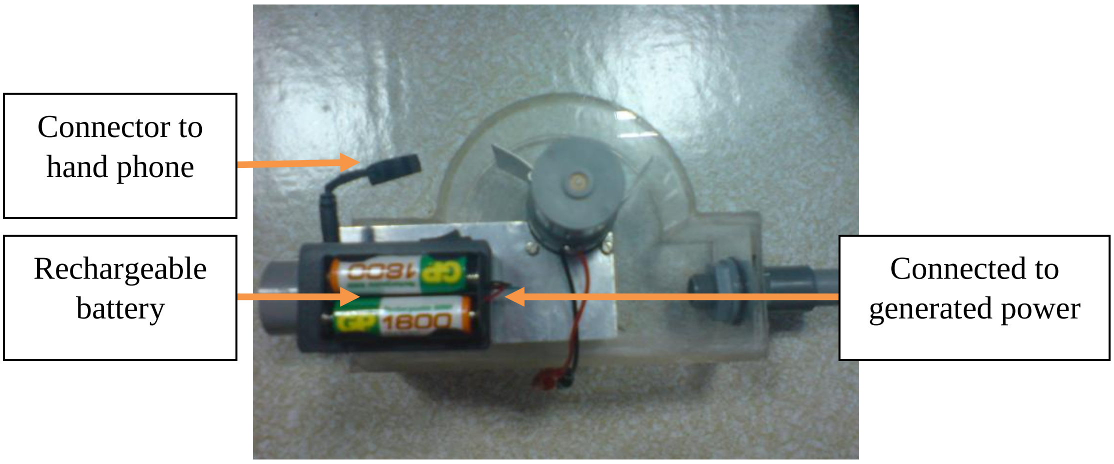
Table 4 Result of circuit testing

Vin (V)	Iin (mA)	Vout (V)	Iout (mA)	Charging condition
1.0	0.061	0.05	0.003	Not charging
2.0	2.415	0.1	0.003	Not charging
3.0	6.934	0.03	0.003	Not charging
3.8	83.50	4.0	11.15	Charging

Completed circuit is attached to the prototype as in Figure 32 (b) (c). The whole project is tested as shown in figure 32(d) and the result is shown in table 5, the hand phone started to charge when the speed of turbine reach 190rpm and above.



(a) Complete circuit part in a box



(b) Front view of complete project

(c) Top view of complete project

(d) Complete testing setup

Figure 31 Complete project

Table 5 Charging Condition

SPEED (rpm)	Current Consumption (mA)	Charging condition
<105	6.934	NO
>190	83.50	YES

Current consumption for charging mode : 83.50mA

Hand phone battery capacity : 900mAh

Time taken to fully charged the hand phone battery

= (900mAh) / (83.50mAh)

= 10.78 hours

The maximum charging period is 10.78hours, the higher the water flow rate and pressure head, the shorter time taken to charge the hand phone. To make the charging period shorter, store the generated power to the rechargeable battery and it is able to fully charge a hand phone battery within 3hours.

4.3.5 System Efficiency

From open circuit test and turbine test, the maximum power generated can be determined as below:

- Speed of turbine : 310.2
- Generated voltage : 7V
- Generated current: 26 mA
- Generated power :

$$P = V I$$
$$= (7V)(26mA)$$
$$= 0.182 \text{ W}$$

From system test where a complete prototype is tested, the voltage and current generated is able to calculate the power generated.

- Average generated voltage : 6.65V
- Average generated current : 17.33mA
- Experimental output power :

$$P = V I$$
$$= (6.65V)(17.33mA)$$
$$= 0.115 \text{ W}$$

Thus, the efficiency of the system is:

$$\text{Efficiency (\%)} = (P_{GENERATED} / P_{MAX}) \times 100\%$$
$$= (0.115W/0.182W) \times 100\%$$
$$= 63.19\%$$

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the studies, water consumption for household can be utilized by putting micro hydro generator to produce electricity. Potential electricity can be generated by micro hydro generator. Micro hydro generator is developed using the concept in hydropower systems which are conventional type and pumped storage type. There are two main parts need to be determined in this project which are the selection of generator and the size of turbine. In this project, permanent magnet generator is chosen and the turbine is designed in a small scale according to the turbine design in the market. After the prototype is completed, several tests can be conducted which are turbine test, open circuit test and system test to determine the how much power can be generated.

In a conclusion, all the tasks planned in this semester are completed on schedule as planned in the Gantt chart. The prototype of Micro Hydro Generator has been built which consists of turbine and generator. This project is able to generate approximate 7V and 17mA. With the help of circuitry part, this generated power is able to charge up hand phone.

5.2 Recommendations

The performance of the project is satisfied where this prototype is able to generate approximately 7V. However, the performance of this project could be improved by optimize the design of the generator, turbine and the nozzle.

One of the recommendations to the turbine is increase number of turbine blades per shaft used is able to increase the speed of rotation of turbine as well. Another recommendation to this project is modify the size of inlet and outlet nozzle. From the pressure formula, the pressure is equal to force divide by area. Hence, the inlet nozzle should be make in a smaller size while the outlet nozzle in a bigger size. With that design, water can be flowed faster from higher pressure to lower pressure.

Besides, installation of gear to the turbine is able to increase the speed of generator. The higher speed of the generator shaft, the more power can be generated. The speed of the water flow inside the turbine is 310.2 rpm. However, after the turbine and generator are connected, the speed decreased to 266.4rpm. Hence, there is still a place to improve the speed of the generator where the maximum speed for the generator work perfectly is 330rpm. Gear can be installed as in figure 32.

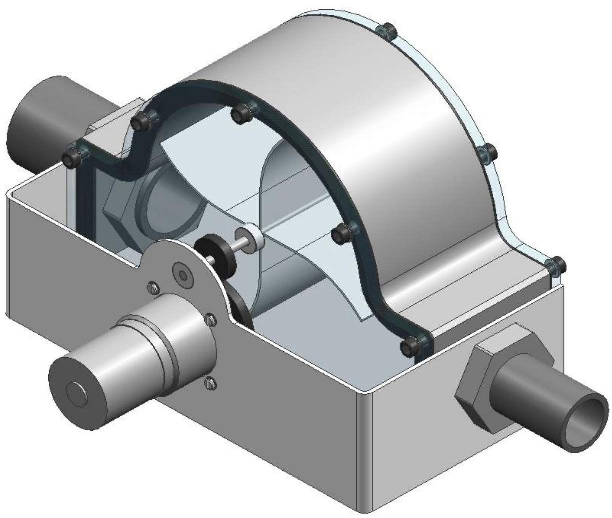


Figure 32 Design of prototype with gear.

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APPENDICES

APPENDIX A

Gantt chart for FYP 1

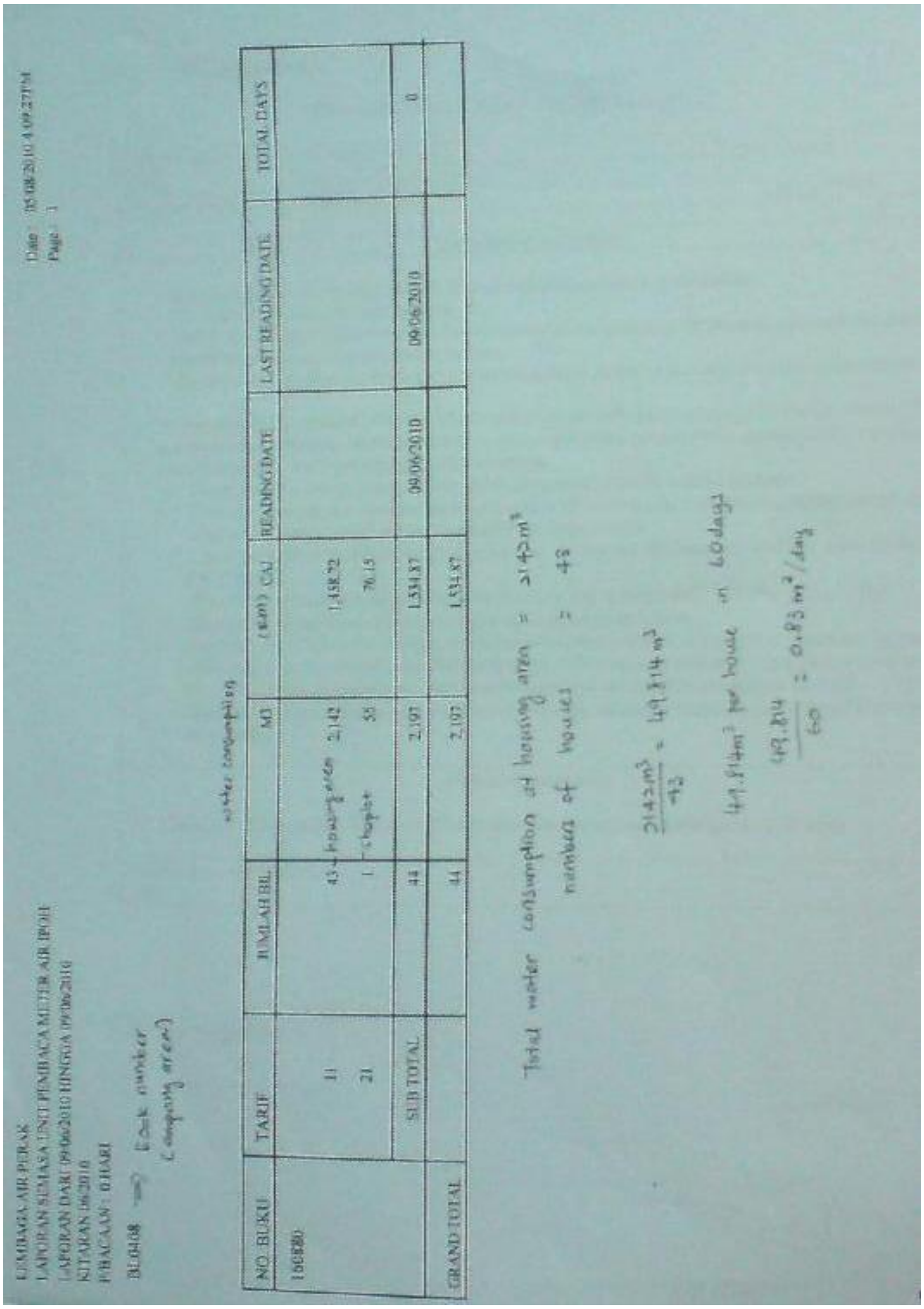
NO	ACTIVITY	WEEK 1	2	3	4	5	6	7		9	10	11	12	13	14
1	Selection of Project Topic								Mid-semester break						
2	Preliminary Research Work														
3	Submission of Preliminary Report				•										
4	Seminar 1														
5	Modification on Existing Prototype														
6	Estimate Power Generation														
7	Submission of Progress Report									•					
9	Seminar 2														
10	Experimental Work on Open Test														
11	Experimental Work on Turbine Test														
12	Submission of Interim Report Final Draft													•	
13	Oral Presentation														•

Gantt chart for FYP 2

NO.	ACTIVITY	WEEK 1	2	3	4	5	6	7	Mid-semester break	9	10	11	12	13	14	15	16	17
1	Research work in project optimization - Gear installation - Electrical Circuit	■	■	■														
2	Circuit Testing - Battery charger circuit - Booster Circuit				■	■	■	■										
3	Submission of Progress Report									•								
4	Combination of Mechanical and Circuitry Part										■							
5	Complete prototype testing											■	■	■				
7	Submission of Dissertation (soft bound)														•			
8	Submission of Technical Paper														•			
9	Oral Presentation															•		
10	Submission of Project Dissertation (hard bound)																	•

APPENDIX B

Water consumption in Perak housing area



LEMBAGA AIR PERAK
LAPORAN SEMASA UNIT PEMBACA METER AIR IPOH
LAPORAN DARI 09/06/2010 HINGGA 09/06/2010
KITARAN 06/2010
P/BACAAN : 0 HARI

Date : 05/08/2010 4:09:27PM
Page : 1

BL0408 → Book number (kampung area)

water consumption

NO. BUKU	TARIF	JUMLAH BIL	M3	(RM) CAJ	READING DATE	LAST READING DATE	TOTAL DAYS
156880							
	11	43 – housing area	2,142	1,458.72			
	21	1 – chapter	55	76.15			
	SUB TOTAL	44	2,197	1,534.87	09/06/2010	09/06/2010	0
GRAND TOTAL		44	2,197	1,534.87			

Total water consumption of housing area = $2142 m^3$
numbers of houses = 43

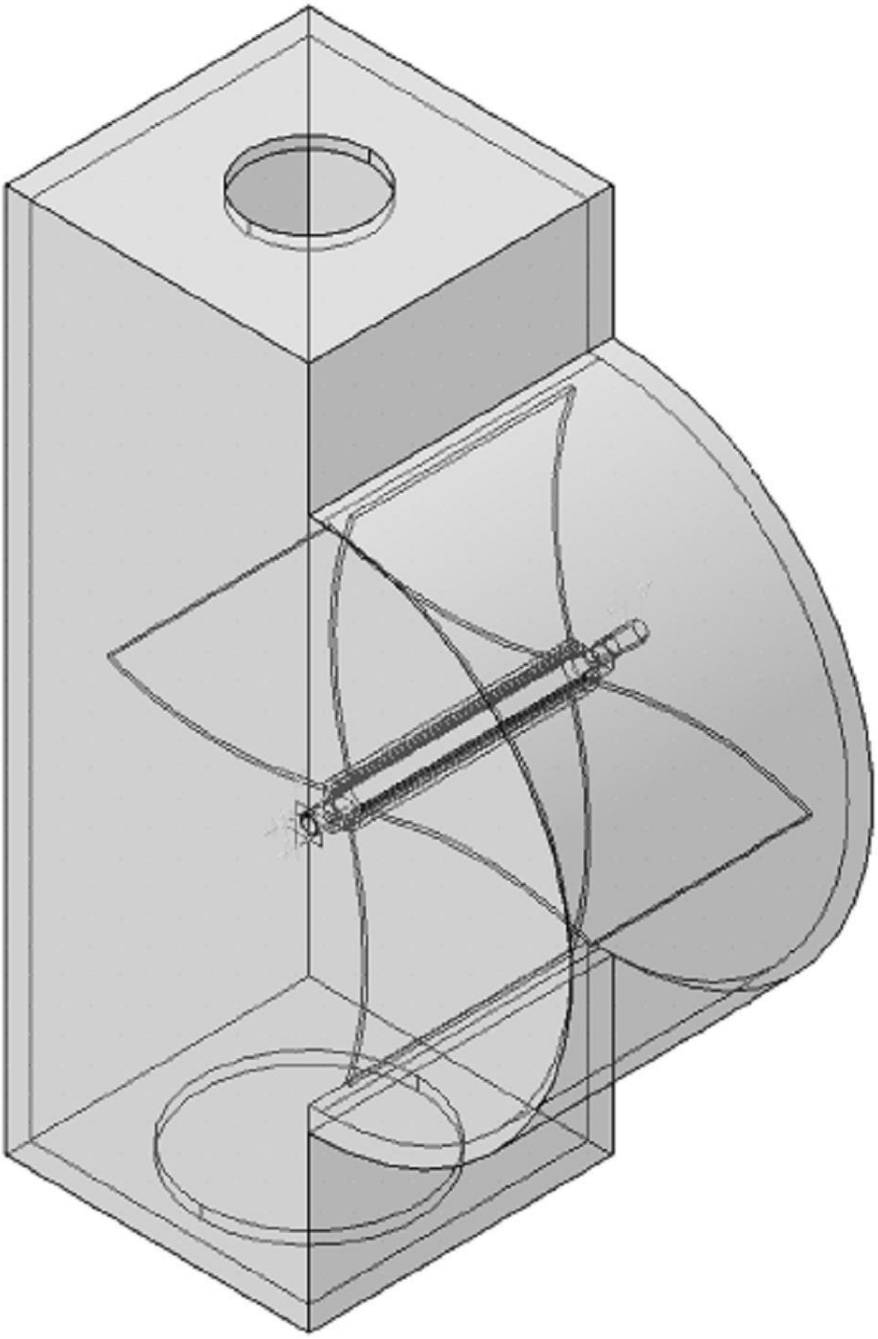
$\frac{2142 m^3}{43} = 49.814 m^3$

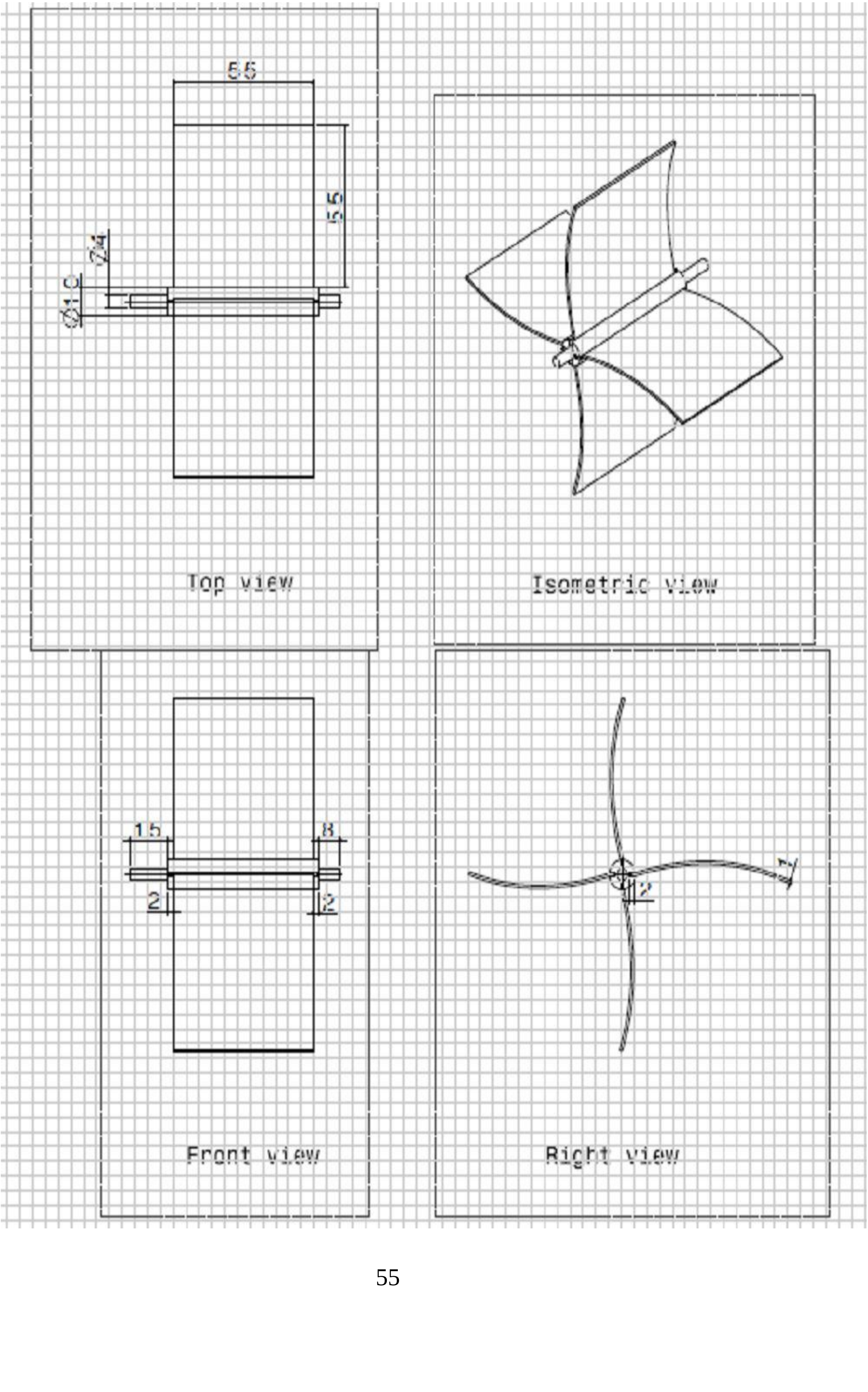
$49.814 m^3$ per house in 60 days

$\frac{49.814}{60} = 0.83 m^3/day$

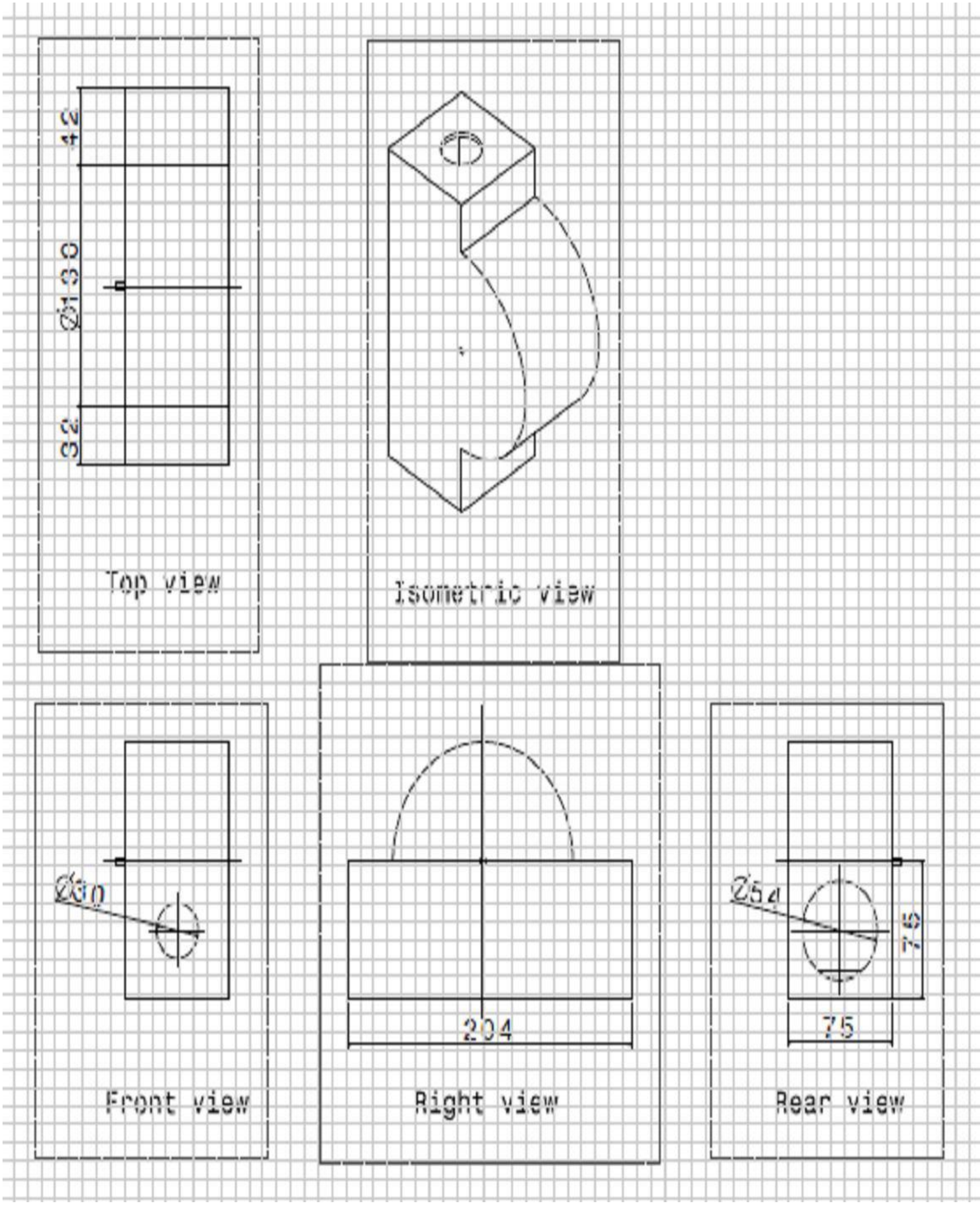
APPENDIX C

Engineering Drawing





55
55
Ø4
Ø10
Top view
Isometric view
15
8
2
2
Front view
1
2
Right view


42
Ø130
32
Top view
Isometric view
Ø30
Front view
204
Right view
Ø54
75
75
Rear view

APPENDIX D

Data sheet for DC generator

Airpax Series 9904 120 52.. **DC Geared Motors**

39mm square flange - plastic geared DC motor

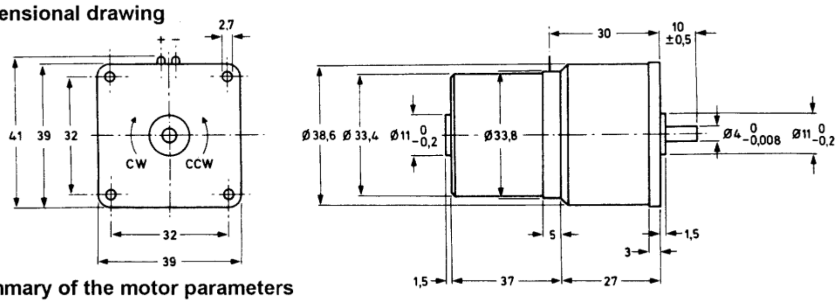
RS 336-343 : 9904 120 52402 **RS 336-321 : 9904 120 52602**
RS 336-337 : 9904 120 52405 **RS 336-315 : 9904 120 52605**

This range of small d.c. motors with integrated gear train is designed for applications requiring quality design and long life drive units. The motor has been designed with a permanent magnet stator system. The reduction gearbox has gearwheels of polyacetal resin. Spark suppression is obtained by a sandwich mounted disc-VDR between commutator and rotor coils. The grey injected plastic housing is highly resistant to chemicals and corrosion. Mounting of the motor is provided for with four M2.5 clearance holes on the flange.

Application examples include:

* vending & coffee machines
* air valve control
* ticket dispensers
* office automation
* printing machines
* entertainment products, scale models

Dimensional drawing



Summary of the motor parameters

Rated working point:

3.5mNm @ 3000rpm (1 Watt, continuous, motor typical life approx. 2500 hours)

Not relevant for all gear ratios - Max. gearbox torque to be considered

Part Number	Rated Voltage (V)	Rotor Resist. (Ohm)	No Load Speed (rpm)	Stall Torque (mNm)	Torque Constant (mNm/A)
9904 120 52 4xx	6	4.7	3900	15	11
9904 120 52 6xx	12	14.5	3900	15	21

Brushes : Carbon

Commutator : flat copper 3 segments

Connections : Solder tags

Thermal res. : 30°K/W (winding/ambient)

Product designed and manufactured in the EEC to ISO 9001 standards

Operating temperature Range	-20 to +60°C
Storage temperature Range	-40 to +70°C
Bearings	Sleeve Bronze, Self Lubricating
Maximum axial play	0.5mm
Housing material	Polycetal Resin - Grey
Gear material	Polycetal Resin
Mass	125g approx.

The values given below apply to an ambient temperature of 22 ± 5°C, an atmospheric pressure of 86 to 106kPA and a relative humidity of 45 to 75%.

catalogue number 9904 120 52..	402	602	405	605	
reduction ratio	9 : 1		50 : 1		
Nominal values					
voltage (d.c.)	6	12	6	12	V
torque	25		125		mNm
speed at nom. load at no load	330 415		60 78		rev/ min
current at nom. load at no load	360 80	185 45	360 80	185 45	mA mA
input power	2.1	2.2	2.1	2.2	W
direction of rotation *	CW		CW + CCW		
max. radial force on the bearings	2		6		N
max. axial force	2		6		N
Limiting conditions					
max voltage (d.c.)	9	18	9	18	V
max. perm. load	37.5		150		mNm

* Viewed from the shaft end

Notes: - The specified rated current values should not be exceeded.

- The gearbox should be externally protected (eg. torque limiter or current control) in systems where torque peaks (or stall) can be expected.

- Indicated no-load-currents are maximum values, to be considered as worst case over the whole motor life. In practice, new motors will show significantly lower values.

Typical Performance curves at 6 and 12V, T_{amb} = 22 °C