OFF GRID PICO HYDRO POWER GENERATOR UTILIZING HOUSEHOLD WATER SUPPLY

MOHD NOR AIDI BIN JAMALUDIN

This dissertation is submitted in partial fulfillment of the requirment for the award of the Master of Electrical Engineering with Honours

Fakulti Kejuruteraan Elektrik dan Elektronik
Universiti Tun Hussein Onn Malaysia

JANUARI 2013

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

W	-	Watts
P	-	Power
V	-	Voltage
I	-	Current
DC	-	Direct Current
AC	-	Alternating Current

CHAPTER 1

INTRODUCTION

1.1 Introduction

The Pico Hydro comes from word Pico which mean very small and hydro which mean water. It refers to electrical energy that comes from the force of moving water used to power equipment. Specifically, Pico Hydro is hydro power with a maximum electrical output from few hundred watts up to five kilowatts (5kW) [1].

Hydropower plant captures the energy of falling water to generate electricity. A turbine converts the energy of falling water into mechanical energy. Then a generator converts the mechanical energy from turbine to electrical energy. The amount of electricity produce by hydropower depends on two factors which are:

1. High of the head (water pressure).
2. Volume of water falling.

For Pico Hydro system, this translates into two categories of turbine:

a. High head and low water flow volume sites
   Impulse turbine is the most efficient choice. The power produced by the impulse turbine comes entirely from the momentum of the water hitting the turbine runners. This water creates a direct push or 'impulse' on the blade, and thus are turbine is called impulse turbine.

b. Low head and high water flow volume sites
   A reaction turbine is the best choice. The reaction turbine, as the name

implies is turned by reactive force rather than a direct push or impulse. The turbine blades turn in reaction to the pressure of the water falling on them. Reaction turbine can operate on head as low as 2 feet but required higher flow rates than an impulse turbine.

Hydro power system of “Pico” size benefits in terms of cost and simplicity from different approaches in the design, planning and installation than those which are applied to large hydro power. On a global scale, a very substantial market exists for Pico hydro system. There are several reasons for the existence of this market.

1. Pico hydro equipment is small and compact. Easy to transport and install.
2. Only small water flows are required for Pico hydro so there are numerous suitable sites.
3. The design principles and fabrication processes can be easily learned.
4. Carefully designed Pico Hydro schemes have a lower cost per kilowatt than solar or wind.

Recently, Pico Hydro is found at rural or hilly area. This system will operate using upper water reservoir which 200 meter head with a flow rate of 1 liter/sto generate one kilowatts (1kW) power [1].

1.2 Problem Statement

This research is conducted to show how potential energy from consuming water distributed to house at town area can be used as an alternative of renewable energy source. The water flow inside the pipeline has potential kinetic energy to spin small turbine for electricity generation. The electricity can be generated as well without interrupting usual activities such as bath, laundry, and are done without extra charge to the water consumption bill. From this project, consumers can save some money on their electricity consumption bill.

1.3 Objective

The objective of this project:

1. Design an efficient Pico hydro system that will function by utilizing water from household water supply.
2. Implement the designated Pico hydro system to residential area in Air Hitam.
3. Do experimental measurements and testing on the performance of the designated Pico hydro system in terms of power (P), voltages (V) and current (I).

1.4 Scope of Work

In this project, there are two parts to be done. Hardware section will be from constructing to examining the actual measurement data while software section will be for designing circuits and expected data measurement.

1. Hardware section will involve the use of car alternator as generator, battery pack as system power storage, inverter circuit for transforming direct current (DC) supply to alternating current (AC) supply and several AC loads.
2. Software section will involve circuit designing and simulation. Electronic circuits that will involve in this project will be carefully design using Multisim Software. Google Sketch Up software will be used to design the cage to mount the generator and also will be used to design the arrangement of items in this project.

Summary for both section are as in Table 1.1.

Table 1.1: Summary for hardware and software section

HARDWARE	SOFTWARE
Generator	Proteus
Inverter Circuit	Google Sketch Up
Power Bank/ Battery Pack	Multisim
Turbine Wheel	

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The hydro power is nearly 2000 years ago when the Greeks used water wheels to grind wheat into flour. In the 1700's, hydropower was broadly used for milling of lumber and grain and for pumping irrigation water. Appleton, Wisconsin became the first operational hydroelectric generating station in the United States, in 1882, producing 12.5 kilowatts (kW) of power. The total electrical capacity generated was equivalent to 250 lights. Within the next 20 years roughly 300 hydroelectric plants were operational around the world. The invention of the hydraulic reaction turbine created the sudden expansion of hydropower.

Nowadays, generating electric using hydro power become well-proven technology, relying on a non-polluting, renewable and indigenous resource; also can integrate easily with irrigation and water supply projects.

2.2 Hydro Electric History

Humans have used falling water to provide power for grain and saw mills, as well as a host of other applications. The first use of moving water to produce electricity was a waterwheel on the Fox River in Wisconsin in 1882; two years after Thomas Edison unveiled the incandescent light bulb. The first of many hydroelectric power plants at Niagara Falls was completed shortly thereafter. Hydropower continued to play a major role in the expansion of electrical service early in this century, both in North America and around the world. Contemporary Hydroelectric power plants generate anywhere from a few kW, enough for a single residence, to thousands of MW, power enough to supply a large city.

Early hydroelectric power plants were much more reliable and efficient than the fossil fuel fired plants of the day. This resulted in a proliferation of small to medium sized hydroelectric generating stations distributed wherever there was an adequate supply of moving water and a need for electricity. As electricity demand soared in the middle years of this century, and the efficiency of coal and oil fuelled power plants increased, small hydro plants fell out of favors. Most new hydro-electric development was focused on huge "mega-projects"[3].

The majority of these power plants involved large dams which flooded vast areas of land to provide water storage and therefore a constant supply of electricity. In recent years, the environmental impacts of such large hydro projects are being identified as a cause for concern. It is becoming increasingly difficult for developers to build new dams because of opposition from environmentalists and people living on the land to be flooded. This is shown by the opposition to projects such as Great Whale (James Bay II) in Quebec and the Gabickovo-Nagymaros project on the Danube River in Czechoslovakia.

2.2.1 Malaysia Hydro Electric History

Table 2.1: Hydro Electric Development in Malaysia

YEAR	DESCRIPTION
1894	A small mining town in Rawang, Selangor. Here, two enterprising individuals Loke Yew and ThamboosamyPillai installed an electric generator to operate their mines
1895	The railway stations in Kuala Lumpur received its first electricity supply
1900	The Sempam Hydroelectric Power Station in Raub, built by the Raub Australian Gold Mining Company became the first power station in Malaysia.
April 1946	Three major projects - The Connaught Bridge Power Station, - The Cameron Highlands Hydroelectric Project &

	- The development of a National Grid
1 September 1949	The Central Electricity Board (CEB) was established and came into operation
1990	TNB was formed in 1990 by the Electricity Supply Successor Company Act

2.3 Previous Studies

The Micro Hydro Centre at Nottingham Trent University grew out of the research work of Nigel Smith, which began in 1985. His PhD work in collaboration with ITDG (now Practical Action) solved the problem of how to control a stand-alone induction generator with a robust electronic controller. Akkal Man Nakarmi, an engineer in Kathmandu, had already discovered that standard induction motors connected to excitation capacitors were a reliable and cost-effective option for micro-hydropower in Nepal, but he was lacking the technology to control the generator effectively.

Nigel Smith was joined in 1987 by Arthur Williams, who investigated the use of standard pump units as turbine-generators, completing his PhD in 1992. They went on to design and implement successful demonstration projects using induction generator technology in the UK and later in Nepal and Pakistan, funded by the UK "Overseas Development Administration" through ITDG.

GeorgiosDemetriades, from Cyprus, began work on development of a low-head turbine design, completing his PhD in 1997. He was followed by DronaUpadhyay from Nepal, who researched the flow through the turbine using Computational Fluid Dynamics (CFD) and proposed improvements to the design.

From 1997, the UK Department for International Development (DfID) and research and development of standardized Pico hydro systems (up to 5kW), suitable for batch manufacture in developing countries and installation with a minimum of skilled engineering inputs. The project developed the "Pico Power Pack" suitable for relatively high head schemes, using a Pelton turbine. Phil Maher joined the team working on this project. An international network was developed, with members in more than 40 countries, to disseminate information and to enable an interchange of ideas and experiences. Between 1997 and 2001, a regular "Pico Hydro" Newsletter was published.

This project was followed by further research on pumps as turbines by Arnaldo Rodrigues (again using CFD) who worked closely with a researcher based at the Technical University in Karlsruhe, Punit Singh. In 2004, research and development of low head turbines continued with the awarding of a grant from the Leverhulme Trust. Dr Robert Simpson was the main researcher on this project, working in collaboration with Practical Action in Peru.

2.3.1 Case 1: The Eastern Africa office of the Intermediate Technology Development Group (ITDG-EA) in Kenya

The Eastern Africa office of the Intermediate Technology Development Group (ITDG-EA) in Kenya has installed very small 'Pico-hydro' power systems for two remote communities on the slopes of Mount Kenya.

These projects provide over 200 homes with lights and power points. As well as giving light to study by and power to recharge appliances like radios, the electricity also opens up new income-generating possibilities to villagers, from chicken farming to charging points for mobile phones – a social and economic lifeline to health workers, family and markets elsewhere [2].

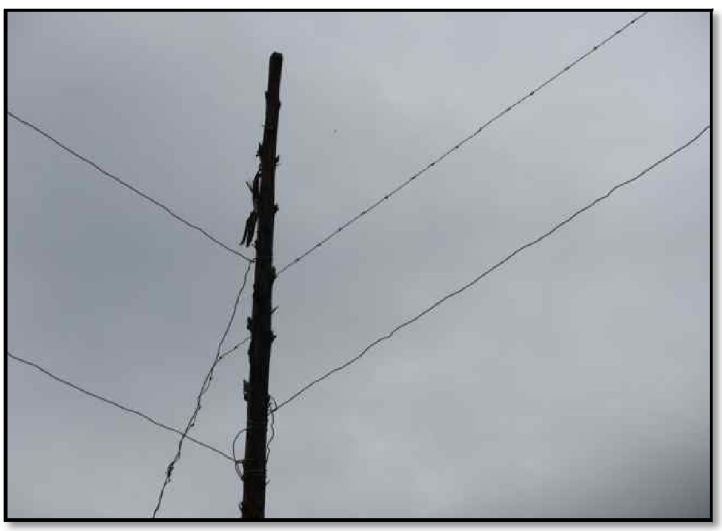

Figure 2.1: Barbed Wire Power Transmission

The schemes' size and design avoid environmental disruption while providing a cheaper and safer alternative to kerosene and lead-based dry cells. Equally important is ITDG's success in bringing about a proposed change of policy in Kenya to help create a decentralized electricity market, allowing micro-schemes such as these to thrive countrywide.

Figure 2.2: Pico Hydro Station

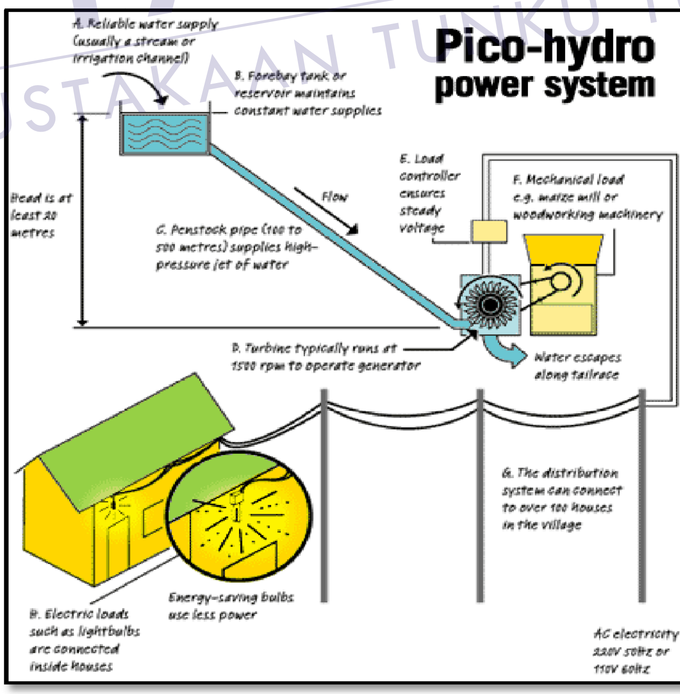

Figure 2.3: Pico Hydro System

2.3.2 Case 2: A Pico Hydro Power Plant for Elementary Lighting in Nepal

In December 2006, RIDS-Nepal installed the first Pico Power Plant prototype made by NHE (Nepal Hydro Electric) in Butwal, producing 650 Watt power by a water flow of 27 liter per second and a negative head of 5 meter ("negative" because the "head" is not "in front" of the turbine providing pressure, but after the turbine producing a vacuum through a conical shaft, and thus "sucking" the water through the turbine).

Another challenge was to install the Pico without any cement, as in a place like Humla where all materials have to be carried in for 15 days from the next road head, or flown in by plane, material becomes unaffordable expensive for the local people. Thus as much as possible only local material, which means stone, wood and mud can be used for the dam, the canal and the power house.

Figure 2.4: Inside Generation Station

RIDS-Nepal installed the Plant in Kholsi village (30°00'25.77" North / Longitude: 81°45.24.00" East / Altitude: 2515 meter above sea level, 745 mbar pressure at 20°C). Kholsi has a good hydro resource with a river flowing just north-west of the village. Hydropower being the most sustainable and locally available renewable resource, thePico-hydro plant was installed at the river which is about 700m from the village in North East direction.

Figure 2.5: Generator While Operating

From June 2000, RIDS-Nepal begins to make WLEDs lights, which RIDS-Nepal got sponsored from the Calgary University in Canada. A survey and estimation was done for 67 houses in Kholsi, two to three lights of 9 WLEDs per household, total 200 lights. The total power consumption is 650 Watts.

Due to the enormous deforestation problems in Humla, RIDS-Nepal puts all wires underground. That helps save the soft pine wood the wires are also much better protected from the monsoon rains, the snow in the winter and the storms in spring time. It is more costly initially, but that pays off quickly, as there is hardly any maintenance needed for years to come.

As a Pico produces just 650 Watt by 220 Volt AC, it just produces 4.5 Amps flowing through the wires. After 1 years running, the Pico was providing nonstop light, very few minor break downs in the underground wire occurred which can easily be handle and repair.

Figure 2.6: WLEDs lights

2.4 Component of Pico Hydro System

There are eight main components to a Pico Hydro System:

1. Water supply, tank and penstock
2. Turbine
3. Generator
4. Charging circuit
5. Battery
6. Inverter
7. Distribution system
8. Electrical loads

Figure 2.7 shows Pico Hydro Power System used in Kenya. They utilize water supply from a spring or small canal to move the turbine.

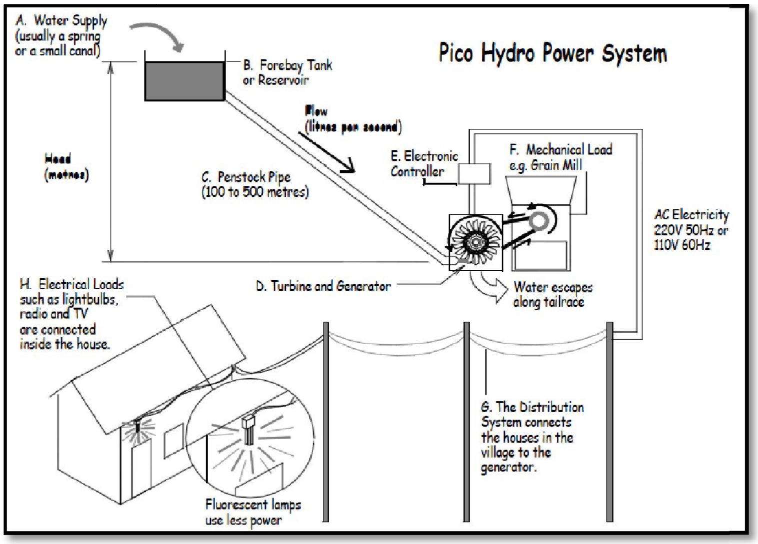

Figure 2.7: Pico Hydro Power System

2.4.1 Penstock

The Pico hydro system penstock begins from the water inlet to the turbine. The water inlet must be directly connected to the end user water outlet for water intake or to the water supply tank. The water intake point must be suitable for generating electricity and also can the supply for daily use. In order to ensure this to main purpose can be done, the Pico hydro should have outlet from the turbine.

2.4.2 Turbine

A turbine converts the energy in falling water into shaft power. There are various types of turbinewhich can be categorized in one of several ways. The choice of turbine will depend mainly on the pressure head available and the design flow for the proposed hydropower installation.

2.4.3 Generator

In electricity generation, an electric generator is a device that converts mechanical energy to electrical energy. A generator forces electric charge (usually carried by electrons) to flow through an external electrical circuit. It is analogous to a water pump, which causes water to flow (but does not create water). The source of mechanical energy may be a reciprocating or turbine steam engine, water falling through a turbine or waterwheel, an internal combustion engine, a wind turbine, a hand crank, compressed air or any other source of mechanical energy.

2.4.4 Battery

Rechargeable battery (also known as a storage battery) is a group of one or more secondary cells. Rechargeable batteries use electrochemical reactions that are electrically reversible. Rechargeable batteries come in many different sizes and use different combinations of chemicals. A charge controller circuit needed to control the charging and discharging process of rechargeable battery. Figure 2.8 shows the graphical picture of charging and discharging process. During charging, the positive active material is oxidized, producing electrons, and the negative material is reduced, consuming electrons. These electrons constitute the current flow in the external circuit. The electrolyte may serve as a simple buffer for ion flow between the electrodes, as in lithium-ion and nickel-cadmium cells, or it may be an active participant in the electrochemical reaction, as in lead-acid cells.

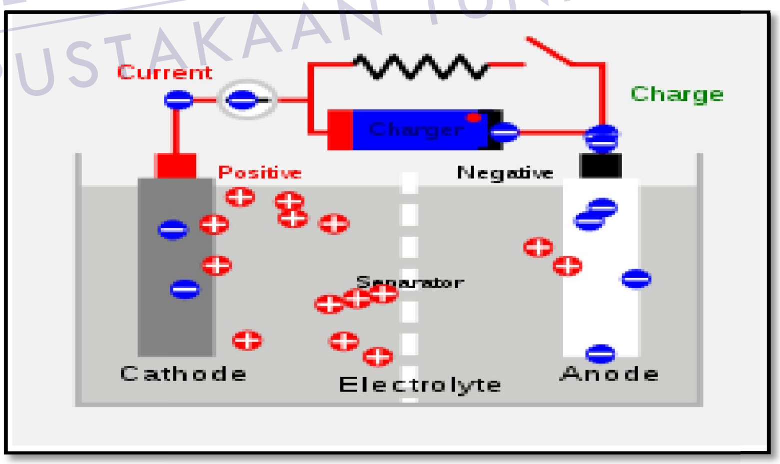

Figure 2.8: Charging and Discharging Process

2.4.5 Inverter

A power inverter is a DC to AC inverter device that is capable of turning DC power, like the power found in batteries or the kind collected from generator, into AC power that is used to run everyday things in the home such as appliances, electronics, and even household lighting.

2.4.6 Distribution system

The distribution system connects the electricity supply from the generator to the room. This is often one of the most expensive parts of the system.

2.4.7 Electrical loads

Electrical loads are usually connected inside houses. This is a general name given to any device that uses the electricity generated. The type of loads connected to a Pico hydro scheme depends largely on the amount of power generated. Using the power wisely can add more benefits. Special lights such a fluorescent bulb, for example, use less power and so more lights can be connected to the same generator.

2.5 Pico Hydro System Planning

The most important part for this project is planning as install ability in resident house. There are many factors that determine the suitability of the system. This includes:

1. The amount of power available from water flow in the pipelines. This includes water
   pressure, volume of water available and friction losses in the pipelines.
2. The type of turbine and available generator type and capacity.
3. The type and capacity of loads to be supplied by the Pico Hydro.
4. The cost of developing the project and operating the system.

Figure 2.9 shows the procedure to plan a Pico Hydro system.

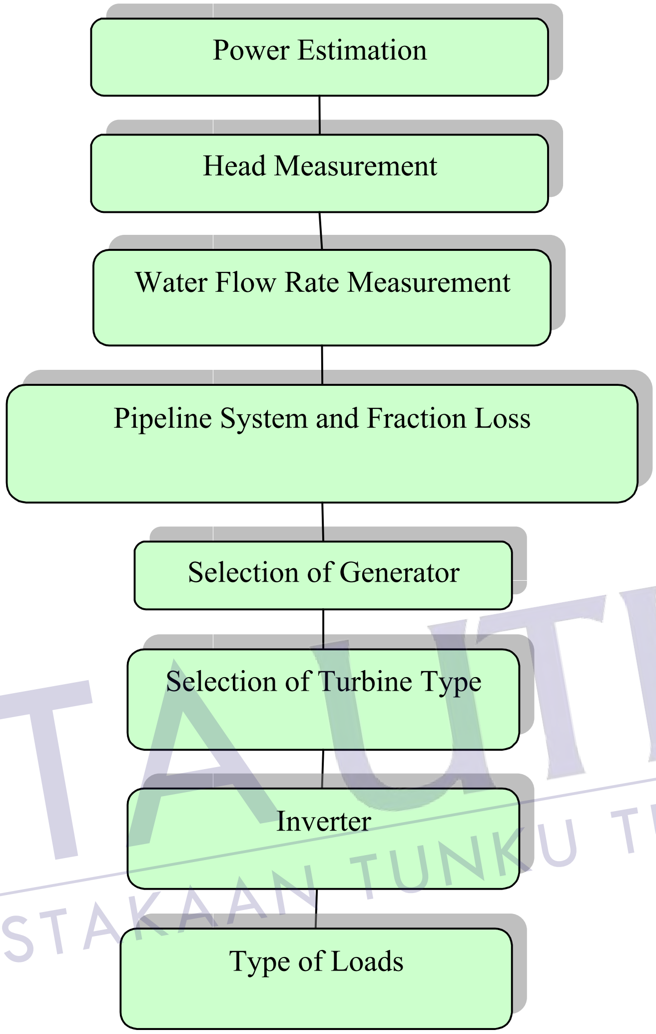

Figure 2.9: Pico Hydro System Planning

2.5.1 Power estimation

Potential energy is a kind of stored energy and the energy of position. The water in a water tank on top of a house is example of potential energy [6]. The stored energy in the tank is converted into kinetic energy (motion) as the water flows down a large pipe call penstock and spin the turbine. The turbine spins a shaft inside the generator, where magnets and coils of wire convert the motion energy into electrical energy through a phenomenon called electromagnetism.

These are the step of water flow:

1. Water in a tank on top of a house flows through a filter that filters dust or sediment in the tank.
2. The water travel through a pipe called a penstock and been blast by high pressure water jet.
3. The force of the water spins a turbine at a high speed.
4. Water flows out of the penstock.

2.5.2 Head measurement

Head rate is very important parameter in hydropower. It is a measure of falling water at turbine which is calculated from begins of penstock to the turbine at the bottom [4-5]. When determine head, we should observed static head first. This is due to the fix high of water tank in our house. For most of resident house, the high of water tank is 3-4 meter from ground.

2.5.3 Water flow rate measurement

In fluid dynamic studies, water flow rate is the volume of fluid which passes through a given surface per unit time. The SI unit is $m^3\ s^{-1}$ (cubic meters per second). In US Customary Units and British Imperial Units, volumetric flow rate is often expressed as ft^3/s (cubic feet per second).

2.5.4 Pipeline system and friction loss

Pipeline system is used to carry water to a turbine. This is commonly termed as penstock which consists of pipe from the reservoir or water tank and valve or water gate that controls the water rate flows.

The generation of electricity for large hydroelectric begins with water flowing from the reservoir into openings on the upstream side of dam to penstocks, which are very large pipes. The water flows down the penstock to turbines at the bottom, spin the turbine and generate power. The proposed Pico-hydro system will have the water source from consuming water distributed to houses so the system must be designed with ability to produce high water pressure to rotate the turbine at the most possible speed and at the same time, the water can be recycled and used for routine activity. Water jet should be installed to the end of penstock so that the turbine rotation speed can be maximized [3].

Friction loss refers to that portion of pressure lost by fluids while moving through a pipe, hose, or other limited space. In mechanical systems such as internal combustion engines, it refers to the power lost overcoming the friction between two moving surfaces.

Friction loss has several causes, including:

1. Frictional losses depend on the conditions of flow and the physical properties of the system.
2. Movement of fluid molecules against each other
3. Movement of fluid molecules against the inside surface of a pipe or the like, particularly if the inside surface is rough, textured, or otherwise not smooth
4. Bends, kinks, and other sharp turns in hose or piping

In pipe flows the losses due to friction are of two kinds which are skin-friction and form-friction. The former is due to the roughness of the inner part of the pipe where the fluid comes in contact with the pipe material, while the latter is due to obstructions present in the line of flow perhaps a bend, control valve, or anything that changes the course of motion of the flowing fluid.

2.5.5 Selection of generator

In electricity generation, an electric generator is a device that converts mechanical energy to electrical energy. A generator forces electric charge (usually carried by electrons) to flow through an external electrical circuit.

Electric generators types depend on the type of generating equipment employed, the electrical energy produced is either DC or AC.

AC generators are classified as single-phase or poly-phase. A single phase generator is usually limited to 25kW or less and generates AC power at a specific utilization voltage. Poly-phase generators produce two or more alternating voltage (usually two, three, or six phase).

DC generators are classified as shunt, series, or compound-wound. Most DC is the compound-wound type. Shunt generators are usually used as battery chargers and as exciters for AC generators. Series generators are sometimes used for street direct the flow of current in one direction. The generator rotating commutators provide the rectifying action [7].

Generating system for a hydro power scheme is selected based on the following concerns:

1. The estimated power of a hydropower system
2. Type of supply system and electrical load: AC or DC
3. Available generating capacity in the market
4. Generator with cost effective

Normally, Pico hydro systems use AC generator either induction or synchronous machine type. This is because the system is used to supply AC electrical appliances and DC generator above 2kW is expensive and has brush gear that required maintenance. Furthermore, DC switch for voltage and current is more expensive then equivalent AC switch.

However, for storing energy purpose in batteries a brush permanent magnet DC generator is preferred. One significant advantage of using DC type of permanent magnet generator over AC generator is that DC generator is designed to provide high currents at minimum voltage requirement for charging of battery and operation of direct current loads. This is related with load type to be supplied. Moreover, permanent magnet generator is selected as it is much cheaper and has smaller overall size rather than of wound field. Other than that, this type of generator is more efficient because no power is wasted to generate the magnetic field.

2.5.6 Selection of turbine type

Selection of turbine to be used is very important in the design and development of a hydropower system. In general, reaction turbine is fully immersed in water and is enclosed in a pressure casing. A hydropower Turbine is a device which converts the energy of flowing water into mechanical energy. The mechanical energy is then converted into electricity by a generator. A typical hydropower plant includes a dam, reservoir, penstocks (water conveying pipes), and a power house which contains the turbine, generator and an electrical power substation. In this project, Pelton type turbine is choose because this Pico Hydro system has low head and high volume of water flow [8]. Figure 2.10 shows the operation of a Pelton type turbine.

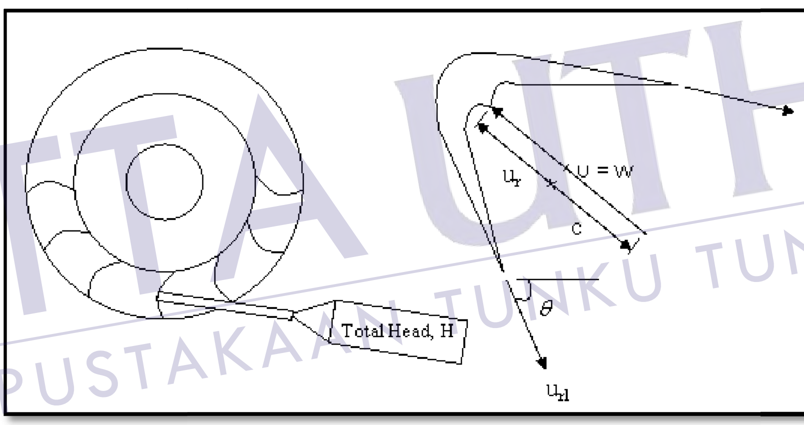

Figure 2.10: Pelton Wheel Turbine

Generally for all hydro turbines,

$P = \rho \times g \times H \times Q \times \eta$

(2.1)

Where

P = power (W),

H = Head (m),

Q = flow rate (m^3/s),

g = acceleration due to gravity (m/s^2),

η = coefficient of efficiency,

ρ=density of water (kg/m^3)

ρ strictly for Pelton hydro turbine,

$$P = \rho \times Q \times c \times (u-c) \times (1+K \times \cos \theta) \quad (2.2)$$

Where

ρ = water density,

u = absolute water velocity at inlet,

K = coefficient of friction 0.85,

θ = relative water angle at inlet (15^o)

2.5.7 Inverter

A power inverter transfers readily available DC power, like from a battery or other stored power source, and turns it into readily usable AC power on the go or at home on devices you would normally plug into a home electrical outlet [13-15].

It is a good idea to add up the wattage used in the home normally by the amount of wattage used in each appliance and electrical item, lighting, etc., and then also give extra wattage for startups and occasional surges that many appliances tend to put out at times. So the amount of wattage in all electrical items give out plus some additional wattage for surges and startups should indicate a close enough measure of the size of power inverter DC to AC needed. Remember that having excess power is much better than having a brown out because it will deplete all of the available power.

The batteries that connect to the inverter should be kept in fairly close proximity to the power DC to AC inverter so that the cables can be short and run a clean and clear signal. Power inverters are not weatherproof and should be kept from getting wet. It should be kept dry like any other electronic device seeing as wetness will destroy the device and cause an unsafe situation.

Deep cycle batteries are highly recommended and most often used with power inverters because they tend to maintain a consistent voltage more efficiently, are longer lasting than conventional batteries, they work well in extreme weather conditions, and they deliver a higher capability of amp surge than a conventional battery ever could carry.

2.6 Conclusion

As conclusion for literature review and previous study, research of renewable energy should be continue and expand from rural area to resident area. Several aspects should be count in before installing Pico Hydro Generation system in residential area especially house. Water pressure from selected source should be measured in order to estimate output power. It also helps to choose right turbine, generator, and maximum load can be support by the system.

In this Pico Hydro project, it is decided to use Pelton wheel for turbine, Denso branded car alternator as generator, 12 volts 5 amperes battery as battery bank, 12 volts charger controller, an inverter that converts 12volts DC to 240 volts AC and a three pin socket outlet.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology is a flow of actions which is taken in designing and developing the project. The process includes design, analysis, implant, and getting the expected result. There are two parts, which is research work and project development. First and foremost, research is made related to the project and problems occur. The next step is designing electronic circuit using PROTEUS and MULTISIM software and designing prototype using Google Sketch Up software.

This stage is the most critical stage in research as it determines the feasibility and achievability of the proposed Pico Hydro Generation system. There are factors that influence the feasibility and achievability of the system. This includes:

i. Amount of power available from the water flow inside the pipeline. This depends on the water pressure, amount of water available and friction loss in the pipeline.
ii. Turbine type and the availability of required generator type and capacity.
iii. Type and capacity of electrical load to be supplied by the Pico Hydro Generation system.
iv. Cost of developing the project and operating the system.

3.2 Power Estimation

There are three types of powerIn Pico Hydro power system. All of these power are related to each other, however only one power is needed. The first kind of power is known as hydraulic power or water power, which comes from the water flow in the channel. Second type of power comes from the rotating turbine, known as mechanical power. The third type which is the one that is needed by consumer is electrical power. Electrical power is produced when the generator or in this case, car alternator operates.

Power could not be created nor be destroyed. All it can do is converting to another type of power. In this project, the water power (or hydraulic power) will always be more than the mechanical and electrical power. This is because as the power is converted from one form to another, some is lost at each stage as shown in Figure 3.1.

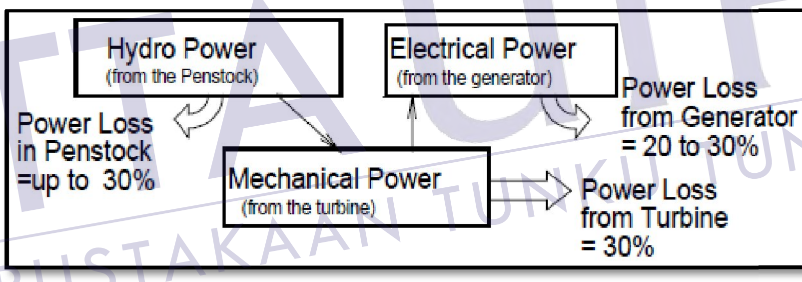

Figure 3.1: Power Loss during Conversion

Usually, on a well designed Pico Hydro Generation system approximately one third of the power of the nozzle will be lost. A further 20% to 30% will be lost in the generator when mechanical power is converted to electricity. After all, there are four steps involved during this power conversion. Only electrical power will be considered in the design.

[1] N. Smith and G. Ranjitkhar, “Nepal Case Study–Part One: Installation and performance of the Pico Power Pack,” Pico Hydro Newsletter, April 2000.

[2] P. Maher. “Kenya Case Study 1 at Kathamba and Case Study 2 at Thima.” Available at: http://www.eee.nottingham.ac.uk/picohydro/documents.html#kenya

[3] P. Maher and N. Smith, “Pico hydro for village power: A practical manual for schemes up to 5 kW in hilly areas,” 2nd ed., Intermediate Technology Publications, May 2001.

[4] J. Mariyappan, S. Taylor, J. Church and J. Green, “A guide to CDM and family hydropower,” Final technical report for project entitled Clean Development Mechanism (CDM) project to stimulate the market for family-hydro for low income families, IT Power, April 2004.

[5] A. Williams, “Pico hydro for cost - effective lighting”, Boiling Point Magazine, pp. 14-16, May 2007.

[6] H. Zainuddin, M. S. Yahaya, J. M. Lazi, M. F. M. Basar and Z. Ibrahim, “Design and Development of Pico-hydro Generation System ForEnergy Storage Using Consuming WaterDistributed to Houses”, International Conference on Computer, Electrical, and Systems Science, and Engineering 2009 (CESSE '09) at Bali, Indoneisa, 25-27 November 2009.

[7] Wind stream Power, Permanent Magnet Dc Generator, [online]. Available at: http://www.windstreampower.com/443540_PMDCG.php

[8] A. Harvey, A. Brown, P. Hettiarachi and A. Inversin, ‘Micro hydro design manual: A guide to small-scale water power schemes,’ Intermediate Technology Publications, 1993.

[9] Zahnd, A., Kimber, H. M., Benefits from a renewable energy village electrification system, Renewable Energy, Vol. 34, 2009, pp. 362-368.

[10] A.A. William, R. Simpson, Pico-hydro – Reducing Technical risks for rural electrification, Renewable Energy, Vol. 34, 2009, pp. 1986-1991.

[11] Baines J., William A.A., A test rig for pico hydro Pelton turbines. Pico Hydro, issue 1. UK: Nottingham Trent University; Oct 1997.

[12] Kamaruzzaman Sopian, Juhari Ab. Razak, Pico Hydro: Clean Power fromSmall Streams. Proceedings of the 3rd WSEAS Int. Conf on Renewable Energy, 2009, pp. 414-419.

[13] M. H. Rashid, "Power Electronics Circuits, Devices, and Applications," Prentice Hall of India Private Limited, New Delhi, Second Edition, 1996.

[14] 600 Watt Pure Sine Wave Inverter. Donrowe.com. Retrieved December 14, 2006 [online]. Available at: http://www.donrowe.com/inverters/puresine_600.html.

[15] ABS Alaskan. (2006). DC to AC Power Inverters. Retrieved December 4, 2006 [online]. Available at: http://www.absak.com/basic/inverters.html.