ANALYSIS AND DEVELOPMENT OF HYDRO POWER SIMULATOR

MOHD ADNAN BIN AMRU

BEKC

JUNE 2009

"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation, & Automation)"

Signature : ………………………………………………

Supervisor's Name : EN. HIDAYAT BIN ZAINUDDIN

Date : ……………………………………………….

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MOHD ADNAN BIN AMRU

This Report Is Submitted In Partial Fulfillment of Requirements For The Degree of

Bachelor in Electrical Engineering (Control, Instrumentation, & Automation)

Fakulti Kejuruteraan Elektrik

Universiti Teknikal Malaysia Melaka

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"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references."

Signature : ………………………………………………

Name : MOHD ADNAN BIN AMRU

Date : ……………………………………………….

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بسم الله الرحمن الرحيم

نحمدالله العلى العظيم ونصلى على رسوله الكريم

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Last but not least, I take this opportunity to dedicate this thesis for all electrical engineering students. All suggestions for further improvement of this thesis are welcome and will be gratefully acknowledged.

ABSTRACT

Hydroelectric is a type of renewable energy that is most widely used and developed. It contributes about 88% of the current total energy developed by renewable source. What makes it so popular is because the resource can easily be obtained, and is very environmental friendly. The purpose of this project is to study and analysis the performance of a Pico-hydro system using hydroelectric concept. The next stage is to develop a Hydro Power Simulator to be used in teaching and learning process in power generation related subject. The proposed design utilizes permanent magnet alternator as generator. The system will be able to generate approximately 500W power, which is enough to give a big picture about power generation. Apart from that, the proposed Pico Hydro system is also able to accommodate energy during power shortage condition. Result from this study can give contribution to the future Research and Development (R&D) particularly in the field of small scale hydroelectric generation.

ABSTRAK

Hidroelektrik merupakan tenaga guna semula yang paling banyak dimajukan. Ianya menyumbangkan kira-kira 88-% dari jumlah keseluruhan tenaga yang dihasilkan daripada tenaga guna semula dunia. Sumbernya yang banyak, mudah diperolehi dan pengoperasiannya yang mesra alam meletakkan ia sebagai pilihan utama dikalangan sumber tenaga guna semula yang lain. Projek ini bertujuan untuk mengkaji prestasi sistem janakuasa Piko-Hidro yang telah dihasilkan oleh pelajar sebelum ini. Kemudiannya hasil dari analisis itu, projek ini akan dijadikan simulator untuk digunakan oleh pensyarah dan pelajar sebagai bantuan untuk memahami konsep janakuasa hidro. Sistem ini mempunyai kapasiti untuk menghasilkan kuasa keluaaran kurang daripada 500W, dimana keluaran tersebut sudah cukup memadai untuk memberi gambaran yang komprehensif kepada pelajar tentang janaan kuasa hidro. Hasil daripada kajian ini dapat membantu untuk kerja-kerja pada masa akan datang terutamanya dalam penghasilan hidro elektrik yang berskala kecil.

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LIST OF ABBREVIATIONS

PMA	- Permanent Magnet Alternator
Vrms	- Root Mean Square Value
PV	- Photovoltaic
MW	- Mega Watt
KW	- Kilo Watt
MGD	- Minerals and Geosciences Department Malaysia
SHP	- Small Hydropower
DC	- Direct Current
AC	- Alternating Current
MIG	- Metal Inert Gas
RPM	- Rotation per Minutes
Q	- Flow Rates
H	- Head
g	- Gravity
HP	-Horse Power

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CHAPTER I

INTRODUCTION

1.1 Introduction

Today, the electrical industry has become one of the important industries in the world. This may be due to the increasing demand from the increased population as well as the expansion of industries in the world. This increase demand in electricity causes the depleting of energy resources such as oil, gas and fossil reserves. Therefore, the studies of renewable energy as alternative energy sources become important. The most popular of this kind of energy production is Hydropower.

There are many types of hydropower configuration exist, as stated in the table below:

Table 1.1: Classification of Hydropower [1]

Classification	Generating capacity
Large	More than 100MW
Medium	15-100 MW
Small	1-15MW
Mini	100kW-1MW
Micro	5kW-100kW
Nano	1kW-5kW
Pico	<1kW

Pico Hydro is a term used for hydroelectric power installations that typically produce up to 1 kW of power. The purpose of this project is to study, design and analyze a Pico hydro simulator system using real-time hydroelectric concept. A typical hydropower setup consists of water as the prime mover, a turbine and a generator to generate power.

There are already a lot of Pico-hydro simulators that have been designed, but most of them use computer software to simulate the conditions of a hydropower system. While some of them use direct coupled electric motor to turn the turbine, it is important actually to utilize water power as the prime mover to observe the conditions and main behavior of the actual working system in real-time.

1.2 Project Overview

This project is mainly about analyzing the performance of existing Pico-hydro system that has been developed by former UTeM student, Mohammad Fakhri Bin Abd Ghani. The mentioned project uses Permanent Magnet Generator, which can generate up to 500Watts of power. The purpose of the performance testing is to develop a real-time Pico-hydro simulator to be used by lecturers, to aid them in teaching future students about power generation in hydropower. It will simulate the real conditions in power generation system in small scale, using the very own water as the prime mover.

1.3 Problem Statements

It is not deniable, that there are hundreds of simulators being developed, but not many of them are available for in-depth analysis in indoor environment. Nowadays, the developed small scale hydropower system is developed to supply power to the consumer, and it is not available to be analyzed and modified by students. Some in-lab hydropower simulator, in the other hand, does not simulate the ‘water rotation’ part process, which is very important because it is the main natural source that is being used to generate green power. That is why this project is carried out.

1.4 Project Objective

1. To analyze the performance of existing Pico-hydro system by former UTeM student
2. To improve the workability of the system
3. To plan and apply modification on the system, if needed
4. To develop a Pico-hydro simulator that can be used in indoor environment

1.5 Project Scope

The scope of this project will only involve equipments available in UTeM laboratory. Modifications made will only involve workability of the system, not the physical condition. The generator is able to produce up to 500Watts of power but the output will be used only for testing purposes, which will allow students to observe the behavior of the system in its working state.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Literature review is carried out to gain more understanding about the concept and the designation of hydroelectric system. A lot of references have been considered, including IEEE journals and from other books and printed materials is required to collect information that is related with the project. Basically, power from generator is explained as equation 2.1;

Power from Generator, $P = HQg$ (2.1)

Where P = Power value in Watts (W)

H = Head (can be converted to pressure)

Q = Water Flow Rate

g = Value of gravity force

2.2 Turbines

Turbines are the machines which convert hydraulic energy into mechanical energy which in turn is used in running an electric generator to produce electricity [1]. In general, a turbine consists with buckets along its periphery, connected to a shaft, a mechanism which controls the quantity of water and passages leading to and from the wheel. The high velocity water strikes on the vanes which deflect the water towards outlet and in doing so impart the energy to the runner and cause it to rotate about the shaft axis.

2.2.1 Turgo Impulse/Pelton Turbines

Turgo Impulse/Pelton Turbines has one or more free jets discharging into an aerated space and impinging on the buckets of the runner. In Turgo Impulse, the jet impinges on several buckets continuously, while on the other hand, only single bucket per jet is effective at any instant in Pelton wheel. These turbines may be mounted horizontally or vertically, depending on the system configuration. The Turgo turbine can operate under a head in the range of 30-300 meters. The project utilizes Pelton turbine design to convert water stream into mechanical energy [12], as shown in figure 2.1.

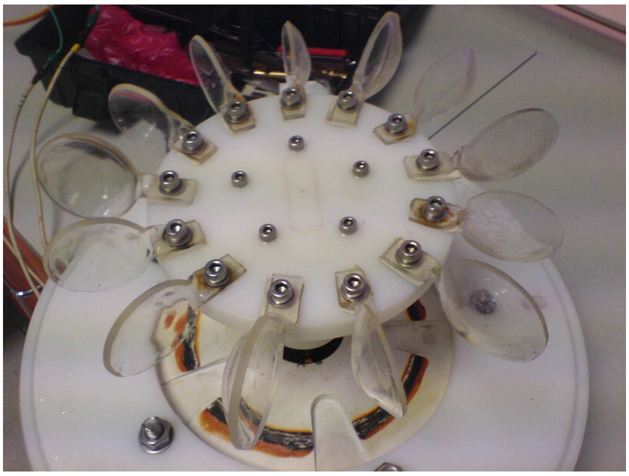

Figure 2.1: Turgo Impulse/Pelton Turbine

2.2.2 Impulse VS Reaction Turbines

Comparisons between impulse and reaction turbines are noted in Table 2.1.

Table 2.1: Comparison of Impulse and Reaction Turbines [12]

Impulse Turbine	Reaction Turbine
Free jet of water impinges on the runner which is exposed to atmospheric pressure.	Flow takes place under pressure in a closed chamber.
Water impinges on only one point but occasionally two or more points at the periphery of the wheel at any instant.	Water enters all around the circumference of the wheel.

Water flow is in the form of a jet, maybe two or more.	The flow maybe radially inward, axial or mixed.
Range of specific speed is less.	Range of specific speed is more.
Entire potential energy is converted into kinetic energy.	Only a portion of potential energy is converted into kinetic energy.
Used only for high head installations.	Comparatively low head wheels.
Efficiency changes very little with size.	Somewhat higher efficiency in larger sizes.
Low speed turbine.	High speed units.
Wheel must not run full with water.	Wheel must run full with water.
Speed of wheel is kept constant under varying loads by changing the jet discharge.	The quantity and direction of flow is controlled by adjustable vanes in accordance with the variation in load.

2.2.3 Turbine performance characteristics

All minimum and maximum performance characteristics for various turbine types are tabulated in Table 2.2.

Table 2.2: Turbine performance characteristic [11]

No.	*Types of Turbine*	*Head application (m)*		*Head Variation (%)*		*Load Variation (%)*	
		Min	*Max*	*Min*	*Max*	*Max*	*Min*
1.	**Impulse**						
	Turgo	40	200	90	110	40	115
	Pelton	100	500	90	110	40	115
	Cross Flow	1	200	60	125	30	115
2.	**Reaction (Mixed Flow)**						
	Francis-horizontal	10	250	65	125	60	115
	Francis-vertical	10	250	65	125	60	115
	Francis-open flume	2	8	90	110	50	115
3.	**Reaction (Axial Flow)**						

	Vertical fixed blade propeller	2	25	85	100	80	115
	Vertical adjustable propeller	16	40	65	125	40	15
	Horizontal Kaplan	2	25	75	115	75	115
	Bulb (Horizontal)	2	25	50	140	30	115
	Rim (Horizontal)	2	25	65	125	85	115

2.3 Pulley System

Pulley systems are used when there is a need to transmit rotary motion [3]. Figure 2.7 below shows a simple system comprise of two pulley wheels and a belt. It is a simple mechanical device to winch up and down a rope. When the motor is turned on it revolves the driver pulley wheel. The belt causes the driven pulley wheel to rotate as well, winding out the rope.

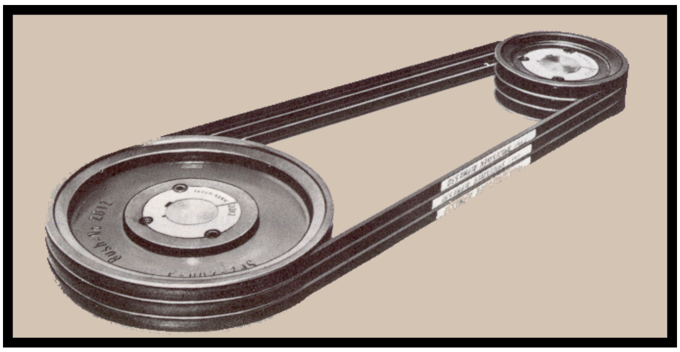

Figure 2.2: Simple System Comprised of Two Pulley Wheels and a Belt [3]

Pulley wheels are grooved so that the belt cannot slip off. Also, the belt is pulled tight between the two pulley wheels (in tension). The friction caused by this means that when the driver rotates the driven follows.

Most pulley wheels have a central shaft on which they rotate. To keep the wheel firmly attached to the shaft it is usual to use what is called a ‘key’. Figure 2.3 below shows a keyed shaft which is pushed through the centre of the pulley wheel. A small rectangular key is then ‘tapped’ into position, holding the shaft and the pulley wheel together. This fitting means that the pulley wheel cannot slip on the shaft.

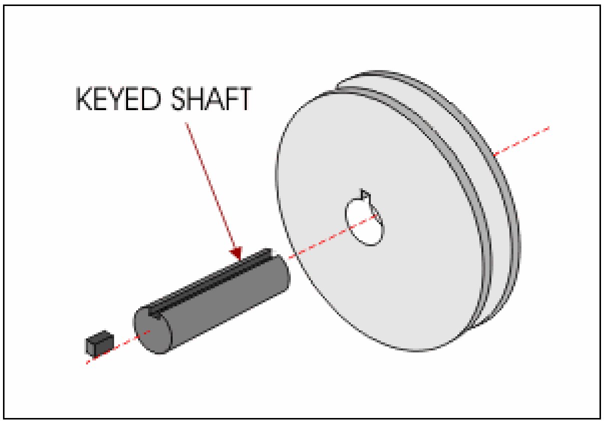

Figure 2.3: Key Shaft [3]

2.3.1 Determining the speed ratio

In this example shown in the figure below, the driver pulley wheel is the larger of the two. Because it is the largest it will automatically be the slowest and output less rpm's than the smaller driven pulley wheel.

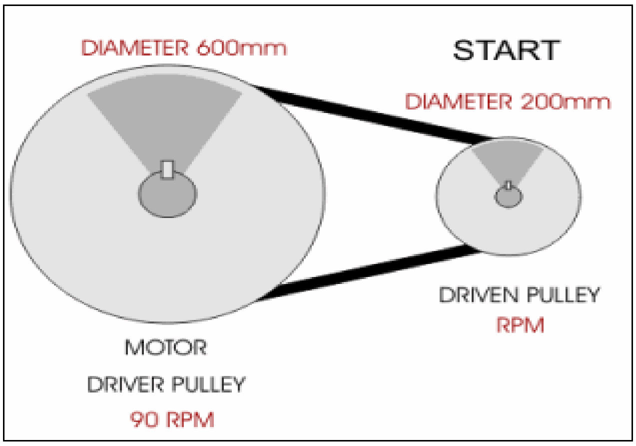

Figure 2.4: Speed Ratio [4]

The diameter of the driver pulley wheel is 600mm and the driven pulley wheel is 200mm. This means for every single revolution of the larger driver pulley wheel, the smaller driven pulley wheel rotates three times. This is due to the velocity ratio. The ratio can be worked out mathematically in different ways. The calculations are shown below. The driven pulley wheel is placed on top of the equation as it is the larger number.

$\frac{\text{Distance moved by driven pulley}}{\text{Distance moved by driver pulley}} = \frac{600}{200} = \frac{600}{200} = 3 \text{ or } 3:1$

The above ratio shows that the larger pulley wheel (the driver pulley wheel) revolves a third of the rpm compared to the smaller driven pulley wheel. Therefore, the driver pulley wheel is slower in which if the rpm of the driver pulley wheel is multiplied by 3, the output rpm of the driven pulley wheel will be found.

Velocity/speed of rotation = RPM of driver pulley x 3 = 90rpm x 3

Of driven pulley = 270 rpm at driven pulley wheel

For this project, pulley system will not be applied because the system can produce transmission loss which will affect its overall performance. This configuration is recommended to be applied in the future to analyze the performance of the system. Moreover, pulley or belt system is believed to increase the performance of the system, with other aspects of modification.

2.4 Nozzle

Figure 2.5: High Pressure Water hit the Runner [5]

A nozzle is a mechanical device designed to control the characteristics of a fluid flow as it exits (or enters) an enclosed chamber or pipe [5]. Figure 2.5 shows the nozzle creates a high pressure water jet which directs the flow at the centre of the turbine buckets. There are some important tolerances which must be taken, such as the amount of water