UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PERFORMANCE CHARACTERISTIC OF WATER REACTION TURBINE FOR PICO HYDRO GENERATION SYSTEM

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology (Power Industrial) with Honours.

by

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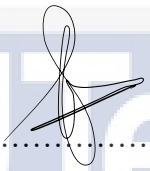
APPROVAL

This report is submitted to the Faculty of Electrical Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Power Industrial) with Honours. The member of the supervisory is as follow:

Signature: 

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ABSTRACT

Pico hydro is a renewable source of energy. Pico hydro can be placed in small streams to generate electricity of five kilowatts (5kw). Hydropower has two turbine types which are reaction turbine and impulse turbine. The objectives of this study were to identify the optimum diameter turbine of Z-blade and to analyze the performance of Z-blade water reaction turbine by using *Matlab*® software. In this study, Z-blade turbine which is reaction type turbine is ideal for the low water head and low water sources in Pico hydro system. This turbine was developed ideally by using the principal equations of conservation of mass, momentum, and energy. Parameters such as water head, diameter turbine, size of PVC pipe and nozzle exit diameter were analysed by using this theoretical equation. The relationship between rotational speed, water flow rate, power output and diameter turbine were generated by *Matlab*® software and discussed based on experimental data taken from Sg Sagil, Tangkak. The Z-blade water reaction turbine able to achieve high value of rotational speed (up to 91 rpm), power output (up to 513kW) and water flow rate of 9.89 L/sec at optimum diameter turbine (0.7m) and low water head condition (5m).

ABSTRAK

Piko Hidro merupakan sumber tenaga yang boleh diperbaharui. Piko Hidro ini ditempatkan dikawasan yang mempunyai aliran air yang rendah, di mana boleh menghasilkan tenaga elektrik sehingga lima kilowatt (5kw). Seterusnya, terdapat dua jenis turbin yang boleh digunakan dalam tenaga air iaitu turbin reaksi dan turbin impuls. Objektif kajian ini adalah untuk mengenal pasti optimum diameter turbin Z-blade dan menganalisi prestasi turbin reaksi air Z-blade dengan menggunakan perisian *Matlab*®. Dalam kajian ini, turbin Z-blade merupakan jenis turbin reaksi air yang sangat sesuai digunakan pada sumber air yang rendah seperti sistem Piko Hidro. Turbin ini dikembangkan secara ideal dengan menggunakan persamaan utama pemuliharaan jisim, momentum, dan tenaga. Parameter seperti kepala air, turbin diameter, ukuran paip PVC dan diameter muncung turbin dianalisis dengan menggunakan persamaan teori ini. Seterusnya, hubungan antara kelajuan putaran turbin, kelajuan aliran air pada muncung turbin, kuasa output turbin, dan turbin diameter dihasilkan menggunakan perisian *Matlab*® dan dibincangkan berdasarkan data experiment yang diambil dari Sg Sagil Tangkak. Oleh itu, ia dapat dilihat bahawa turbin Z-blade mampu mencapai nilai kelajuan putaran yang tinggi sehingga 91 rpm, kuasa output turbin sehingga 513kw dan aliran laju air sehingga 9.89 L/saat apabila optimum turbin diameter pada 0.7m dan keadaan kepala air yang rendah iaitu 5m.

DEDICATION

To my beloved parents, have been my source of inspiration, gave me strength when I'm facing an obstacle, who continuously provide their moral, spiritual, emotional, and financial support.

And to both of my supervisor Puan Nurul Ashikin Binti Mohd Rais and Puan Rozilawati Binti Mohd Nor who guided me and give me a lot of advice to finish this study.

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H	-	Water head
R	-	Turbine diameter
g	-	Gravity = 9.81 m/s
m	-	Mass flow rate
A	-	Nozzle diameter
p	-	Density of water
T	-	Torque
W	-	Output power
η	-	Efficiency
Va	-	Absolute velocity
Vr	-	Relative velocity
U	-	Tangential velocity
Hc	-	Centrifugal head

LIST OF ABBREVIATIONS

PCA	Principal Component Analysis
CFD	Computing Fluid Design

CHAPTER 1

INTRODUCTION

1.1 Background

Pico hydro is a clean energy that uses small flow of water to generate electricity without using non-renewable sources of energy. Specifically, Pico Hydro is hydro power that can generate maximum five kilowatts(5kW) of electricity (Basar *et al.*, 2011).

Hydropower is referring to the flowing of water in the river or ocean that can produces electricity. Simple concepts of hydropower are to use a stream of water that flowing out of the reservoir and then moves the turbine blades. Therefore, the turbine produces energy water which is moving towards mechanical energy. Then an electrical energy was generated from the mechanical energy of the generator. There are two factors that influence the amount of electricity generated by hydropower that is the head and the water flow. The Newton's equation states that electricity cannot be generated unless there is the head and the water flow (Basar *et al.*, 2011).

Head refer to vertical fall of water also known as water pressure. The head occurs when the water height difference for the turbine is taken. Head is also known as vertical distance (feet, meter) or pressure pound per square inch. The table 1 below shows the hydropower classification according to the head (Basar *et al.*, 2011).

Table 1.1: The Hydropower Classification According To The Head (Basar *et al.*, 2011)

Class	Head (Meters)
Ultra-Low Head	H< 3
Low Head	3 < H < 30
Medium Head	30 < H < 75
High Head	H >75

The hydropower classification according to electrical power as shown in table below (Sopian and Razak, 2009).

Table 1.2: Hydropower Classification According To Electrical Power (Sopian and Razak, 2009)

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

Most researcher declare that hydropower more than 1MW is not renewable energy (Sopian and Razak, 2002). This causes substantial deforestation since greenhouse effect occurred when a large reservoir or dam is created (Williams and Simpson, 2009). Meanwhile, Micro and Pico hydro is the best option to generate small power without the

installation of a large reservoir or dam, it is ideal for low head and low water flow. Other than that, Pico hydro is an alternative that does not affect the ecosystem or community living in rural areas and far away from electrical grids.

Since 1990s, there have been many approaches that can be used to analyse the performance of hydro turbine. First, the computing fluid design (CFD) analysis is tool that can assess the performance of hydro turbine. In 2013, CFD analysis was used by Odesola and Orriabre to determine a small-scale Francis turbine based on the theory of simple fluid dynamic turbo machinery. CFD analysis uses two commercial CFD codes which is ANSYS FLUENT and Solidworks Flow Simulation was used for the runner, stay vanes, guide vanes, spiral case and draft tube. This analysis is based on 2D, 3D steady state and single-phase module. Other than that, empirical formula also used to obtain the dimension of the runner based on the suitable head and water flow. In addition, CFD analysis was used to optimize the runner shape and performance. Performance of the turbine at several opening of guide panels was obtained (Odesola and Oririabre, 2013) .

Next, TURBNPRO software is also a tool that used to determine the performance of the hydro turbine. TURBNPRO software has been developed to estimate the size and technical data required in hydraulic turbines. The input data for this program is based on the necessary operating parameters and equipment arrangement such as unit discharge, rated net head, gross head and net head range, and turbine centre line setting for tail water. Based on this program, several output data such as size, speed, dimensional, setting limitation, and typical performance of turbine solution be achieved. In 2016, TURBNPRO software was used by Moona et. al to be selecting and designing Francis Turbine in Hydropower Plants (Mohammadi *et al.*, 2015).

Other than that, *Matlab*® software is also tool that can be used to analyse performance of hydro turbine. *Matlab*® software has been developed to analyze the performance of hydro turbine. The input data for this program is based on the necessary operating parameters and equipment arrangement such as head, flow rate, pipe diameter, turbine diameter and nozzle diameter. Based on these data, the output performance of hydro turbine can be determined. *Matlab*® software is still a new software that was developed to analyse output performance.

1.2 Problem Statement

Today, global climate change and fuels sources are becoming less day after day (Basar *et al.*, 2011). Renewable energy such as Pico hydro has potential to overcome this problem. Previously, computing fluid design (CFD) software uses a turbine design parameter such as inlet velocity and outlet pressure, nozzle interface, wheel and diffuser, and symmetry boundary conditions for the side walls (Wang, Piechna and MÜller, 2012). These parameters need to be determined first to analyse the output performance. Engineers need to design the turbine before this software can be used. This software is difficult to use as it required a lot of knowledge in designing a hydro turbine. Meanwhile, the *Matlab*® software only required the theoretical equation method to analyse the performance of hydro turbine. Other than that, *Matlab*® software can analyse data faster than other software. Since *Matlab*® software is new, the number of researchers that uses this software still limited.

1.3 Objective

The objectives of this project are:

1) To identify the optimum diameter turbine of Z-blade water reaction turbine using *Matlab*® software.
2) To analyze the performance of Z-blade water reaction turbine using *Matlab*® software.

1.4 Scope of study

This project will focus on analyzing the performance of Z-blade water reaction turbine and identify the optimum diameter of Z-blade water reaction turbine using *Matlab*® software. A few parameters such as head, diameter turbine, size of PVC and nozzles exit diameter will be analyse by using this theoretical equation. The parameters that will be affected on the performance are:

1) Head : 3m and 5m
2) Diameter turbine : 0.4m until 1.7m
3) Size of PVC (diameter pipe): 1 inch
4) Nozzles exit diameter : 8mm

1.5 Significant of Study

This study will be carried out to analyzed performance characteristic of water reaction turbine for Pico hydro generation system using Z-blade model. The advantages of using Z-blade turbine in Pico hydro generation system are:

1) The efficiency of turbine will increase.
2) The output performance will be better.
3) The manufacturing cost will decrease.

CHAPTER 2

LITERATURE REVIEW

2.1 Renewable Energy.

Renewable energy is energy derived from the natural and continuous energy flow that requires place in the local environment (Twidell and Weir, 2010). Renewable energy is also known as a clean and environmentally friendly sources of energy (Panwar, Kaushik and Kothari, 2011). That energy can also reduce impact of greenhouse and global warming because non-renewable energy and resources such as fossil fuels are not being used.

2.1.1 Sources of Renewable Energy.

There are many sources of renewable energy that are commonly used to generate electricity which is sun, wind and water. Each of these sources have their own advantages.

2.1.1.1 Solar energy

Solar energy is renewable energy sources that can generate electricity. There are many advantages to using solar power in electricity generation. However, not all sites can use solar energy, especially in remote area. This is because the high sunlight is needed to generate electricity. Solar Thermal Electricity System is a tool which uses solar radiation to produce electricity using solar thermal energy. The solar energy uses heat collected

from sunlight to convert it into electrical power. The figure below shows schematic diagram of a solar thermal conversion system (Panwar, Kaushik and Kothari, 2011).

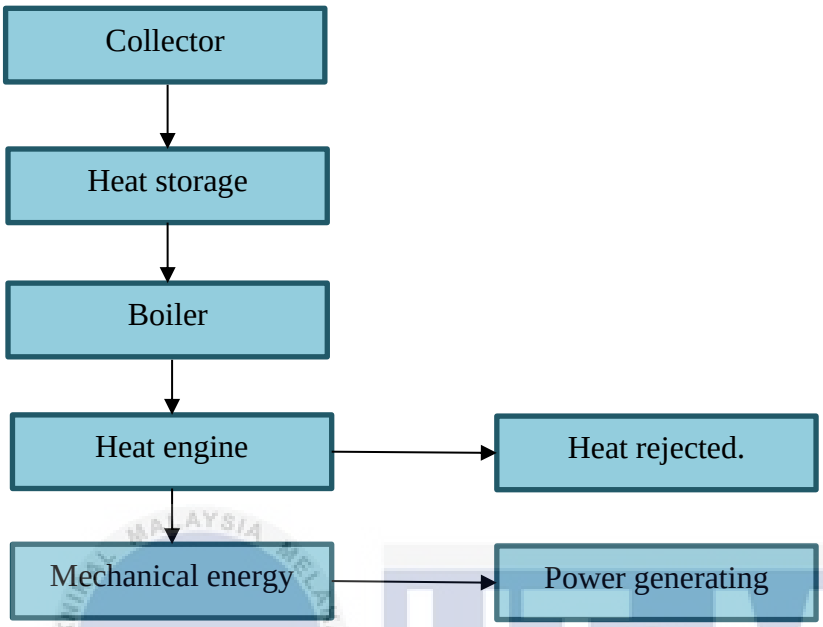

Figure 2.1: Schematic diagram of a solar thermal conversion system (Panwar, Kaushik and Kothari, 2011)

However, the cost of generating electricity via solar energy is more expensive rather than conventional power stations.

2.1.1.2 Wind Energy

Wind energy is the movement of air that produces kinetic energy. Wind main role is to transforms the energy generated in wind power to electricity or to mechanical power by using wind turbines. In Malaysia, the application of wind energy harvesting is still limited (Panwar, Kaushik and Kothari, 2011). The disadvantages of wind energy are the wind turbine must be located at higher ground. Other than that, the availability of wind in Malaysia are highly depends on monsoon.