DEVELOPMENT OF RUN-OFF PICO HYDRO GENERATION SYSTEM FOR LOW HEAD WATER RESOURCES

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" I hereby declare that I have read this fully report entitled "*Development Of Run-Off Pico Hydro Generation System For Low Head Water Resources*" and found that it has comply the partial for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

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Date : 01/06/2015

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

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“I declare that this report entitled “Development Of Run-Off Pico Hydro Generation System For Low Head Water Resource” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.”

Signature : ………………………………………………………

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Date : 01/06/2015

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ABSTRACT

This project is concerned on the analysis performance of simple cross pipe water turbine with low-head (below then 20 meter) and ultra-low flow of water resource .The cross-pipe turbine is made of Galvanized Iron (GI) with half an inch. The cross pipe turbine is also called Z-Blade turbine. Theoretical investigation has shown the Z-Blade turbine has reasonable hydro as mechanical energy conversion of about 50% and this energy conversion efficiency would be improved when the blade spins faster. The Z-Blade turbine has shown good potential to be used for ultra-low hydro resources condition (less than 2 litter/second).When the diameter of pipe is smaller, it will spin faster under constant water head resource. The main advantages of this turbine are very cheap, can be locally made due to material easily to find and no expertise works needed. This project will analyse the performance based on experimental data collected from different test carried out on two simple reaction water turbine prototypes. The factors that will influence the experimental result includes the water flow, turbine diameter, and number of nozzles, size of the turbine and its rotational speed. The suitable design for layout of hydro system is presented to obtain a ultimate power output of the pico hydro generation.

ABSTRAK

Projek ini membincangkan prestasi analisis turbin paip silang mudah dengan kepala rendah (di bawah 20 meter) dan aliran pada kadar rendah sumber air. Turbin rentas paip diperbuat daripada Galvanized Iron (GI) dengan setengah inci. Turbin paip silang juga dipanggil turbin Z-Blade. Kajian teori telah menunjukkan turbin Z-Blade mempunyai jumlah yang munasabah sebagai penukaran tenaga mekanikal kira-kira 50% dan ini menyebabkan kecekapan penukaran tenaga akan bertambah baik apabila bilah berputar lebih cepat. Z-Blade turbin telah menunjukkan potensi yang baik untuk digunakan untuk ketinggian yang rendah ultra hidro sumber keadaan (kurang daripada 2 liter / saat). Apabila diameter paip semakin kecil, ia akan berputar lebih cepat apabila sumber ketingggian air tidak berubah. Kelebihan turbin ini adalah ianya mudah di buat, sumber mudah didapati, dan tidak memerlukan kepakaran untuk membina. Projek ini akan menganalisis prestasi berdasarkan data eksperimen yang dikumpul daripada ujian yang berbeza dijalankan ke atas dua reaksi mudah prototaip turbin air. Faktor-faktor yang akan mempengaruhi keputusan eksperimen termasuk ketinggian sumber air , aliran air, diameter turbin, dan bilangan muncung paip, Saiz turbin dan kelajuan putaran. Reka bentuk yang sesuai bagi susun atur sistem hidro dibentangkan untuk mendapatkan keluaran kuasa yang optimum dalam generasi Pico hidro.

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A Total nozzle exit area (m^2)

d_e Nozzle equivalent diameter (m)

D Nozzle diameter (m)

d Acceleration due to gravity (m/s^2)

H Water height in reservoir (m)

H_c Centrifugal head (m)

K_g Specific speed for turbines = $\frac{\omega\sqrt{Q}}{(gH)^{\frac{3}{4}}}$

$\dot{m}$ Mass flow rate of water through the turbine (kg/s)

$*\dot{m}$ Non-dimensional mass flow rate

Ƞ Efficiency of conversion of potential energy to work

P_c Centrifugal pressure (N/m^2)

Q Volume flow rate (m^3/s)

p Density of water (kg/m^3)

R Radius of the rotor (m)

T Torque ($N.m$)

T_s Torque when turbine is stationary ($N.m$)

$*T$ Non-dimensional torque

$\dot{W}$ Output power (W)

$*\dot{W}$ Non-dimensional power

ω Angular velocity of the rotor (s^{-1})

$*\,\omega$ Non-dimensional angular velocity

U Tangential angular

$*\,V_a$ Non- dimensional absolute velocity

$*\,V_r$ Non- dimensional relative velocity

$*\,U$ Non-dimensional tangential velocity of nozzles.

V_r Relative velocity of water with respect to the nozzle (m/s)

$\dot{m}_s$ Mass flow rate of water through the turbine when it is stationary (kg/s)

V_a Absolute velocity of water leaving nozzle with respect to a stationary observer (m/s)

CHAPTER 1

INTRODUCTION

1.1 Introduction

This part is about research on alternative ways to generate electricity is going aggressively caused by the dependence on non-renewable energy sources is diminishing. The Hydro generation is one of the energy sources that have yet to be fully explored.

1.2 Background

Hydropower can be an alternative, non-polluting and also environment not cancerous way to obtain vitality. Hydropower is founded on basic principles. Flowing water turns a turbine, the turbine will spins a generator, and an electricity is produced. Many other components may be in a system, but it all begins with the energy with the moving water. The use of water falling through a height has been utilized as a source of energy since a long time. It is actually the best sustainable electrical power system identified by any man meant for mechanized electrical power sales and even for the electricity generation. In the previous times, waterwheels were used extensively, but during the beginning of the 19th Century with the invention of the hydro turbines that the use of hydropower got attention.

Non-renewable power assets for example oil, fossil fuel, gasoline as well as nuclear era cannot be renewed as soon as it is been utilized. These kind of sources have an impact towards the earth as it can certainly trigger the green house effect as well as environment concern. Besides that, the renewable energy has been pointed as an alternative due to its limitless sources and environmentally friendly. Hydro-power is actually among green power and its particular be able to upcoming strength technology that cannot be underestimated.

Pico hydro generation system will operate using upper water reservoir within few meter from ground. This type of water in that case pass downhill to create “head” in the piping procedure and increase the speed of the best switching procedure. Consequently, a turbine is going to spin a alternator plus manufacture electric power. Pico hydro electricity generating is definitely ways to address a generating with electric power. The reaction turbine is considered inefficient and yet uncontrollable for low-head. This project will be focused with a design fresh layout of simple reaction turbine as a problem solver.

1.3 Problem Statement

Natural and unnatural disaster has occurred in environment due to the actions of human hand polluting it. Almost 50% of main contaminants on earth associated with polluted supplies mainly in the automobile exhausts, commercial as well as electrical energy era actions. The particular worst allergens regarding sulphur monoxide and also carbon dioxide monoxide suspending inside the oxygen due to use of non-renewable vitality options. Actually, 80% associated with electrical power produced through the energy vegetation make use of that utilizes fossil fuel, gasoline as well as nuclear in support of 20% created green power resources [1]. The actual Asian countries Off-shore area creates 32% associated with worldwide hydropower in 2010. Other than that, any level for opportunity electrical power is certainly endlessly on the market, even so the enactment connected with hydropower is usually underestimated plus underutilized. Theoretically exploitable prospective supplied will be 18, 000TWh/year as well as the cheaply exploitable prospective supplied will be 8, 000TWh/year [2, 3].

Besides an engineering with hydroelectric elaborate delivers virtually no waste material plus and also carbon emissions place is noticeably more affordable, nonetheless massive dams is going to cut off a pass of stream plus cause a problems in any local environment. It means, there are more simple and easy to handle hydro power generation invented. Pico hydro is a creatively invention that produce smaller output in power generation compared with other mega hydroelectric [4]. Smaller hydro technological innovation pledges good efficiency qualitative dividends to the economy while conserve the global environment. As a result, several nations around the world have taken the particular motivation in providing electricity to community [6]. According to date, almost all of the smaller along with tiny hydro sites are generally nevertheless to get looked into, meanwhile a lot of the huge hydropower sites happen to be used [5, 6]. As yet, the quantity of research still undergo for very low head water resource as during the drought season ,the flow rate of water produce within the head of water will be also decrease[4].

According to the all above statement, this project objectives is to develop a low head pico-hydro generation system with a small amount of water flow(run-off-river). Keeping the aspect in mind that the reaction of water turbine developed with low cost and simple manufacture.

1.4 Objective of Project

The following objectives of the project are:

1. To design a run-off Pico hydro turbine using a low head water resources.
2. To study the performance of Pico hydro by using Z-blade GI (galvanized Iron) material.
3. To determine the suitable length of turbine blade and the diameter of nozzle at the end of blade turbine.
4. To analyse the output run-off Pico hydro generation within suitable output variable.

1.5 Scope of Project

The scope of this project are:

1. The head is supplied by water reservoir for 4 meter .
2. The turbine material is GI type (galvanized Iron) will be tested for its performance for the suitable length and suitable diameter of the turbine nozzle.
3. The experimental process will be conducted on the test rig that has been built.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will integrates mainly on the theory and current development in Pico hydro generation system. The chapter is divided into two parts which is Concept of turbine, Revolution of Z-blade and basic design.

2.2 Pico Hydro Generation System

For hydro generation system, there is a classification of hydro according to its output range of power generated as shown in figure 1. Pico hydro is a type of hydro generation as its can generate maximum power less than 5 kW.

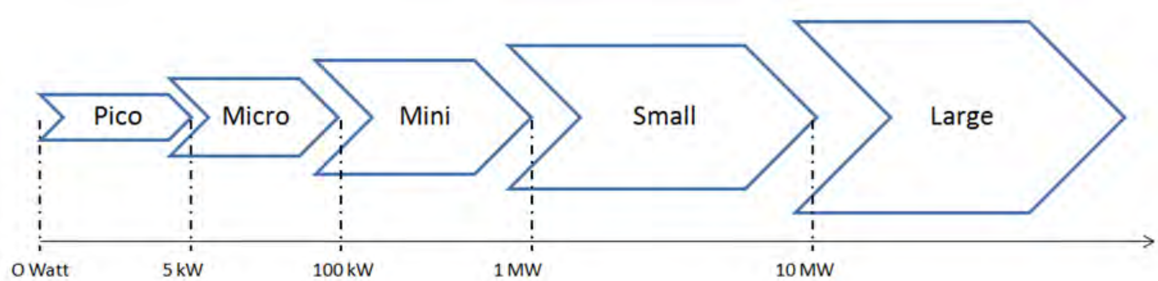

Figure 2.1: Classification of hydro power according to power output [4].

According to S.A. Abbasi and Naseema Abbasi [7], sources such as ocean waves, tides and sea water does not fall within the renewable energy sources even use water as a medium of power generation. According Sopian K [4] also recognize hydropower generating more than 1MW be classified as non-renewable energy. This is caused by factors such construction of reservoirs and dams that cause environmental damage.

Hundreds of years ago, the construction of large dams is the only way to generate electricity. However, the construction of large dams would cause disruption to the natural flow of small rivers. Besides, rampant deforestation that is used to create a vast reservoir can lead to a significant impact on the greenhouse effect. This proves that there is no difference between fuel consumption and hydropower to generate electricity. Pico-hydro is one alternative way to generate electricity without damaging the environment. Due to several factors, the use of pico-hydro is the right choice for assisted with smart technology and cost-effective and helps to supply energy to remote communities of the electrical grid.

2.3 Head and Flow

Head and flow is a main part of pico hydro power systems. Both are important to spin the turbine and produce electricity. The output power is directly proportional to the head and flow of the water. So, when the head of water increase, the flow of water increase thus the output power generation will be increased. Fig 2.2 shows the characteristic of head and flow of water connection that relates to the output power as described by M. F. Basar. No output power will be obtain if there is no flow nor head of water [4].

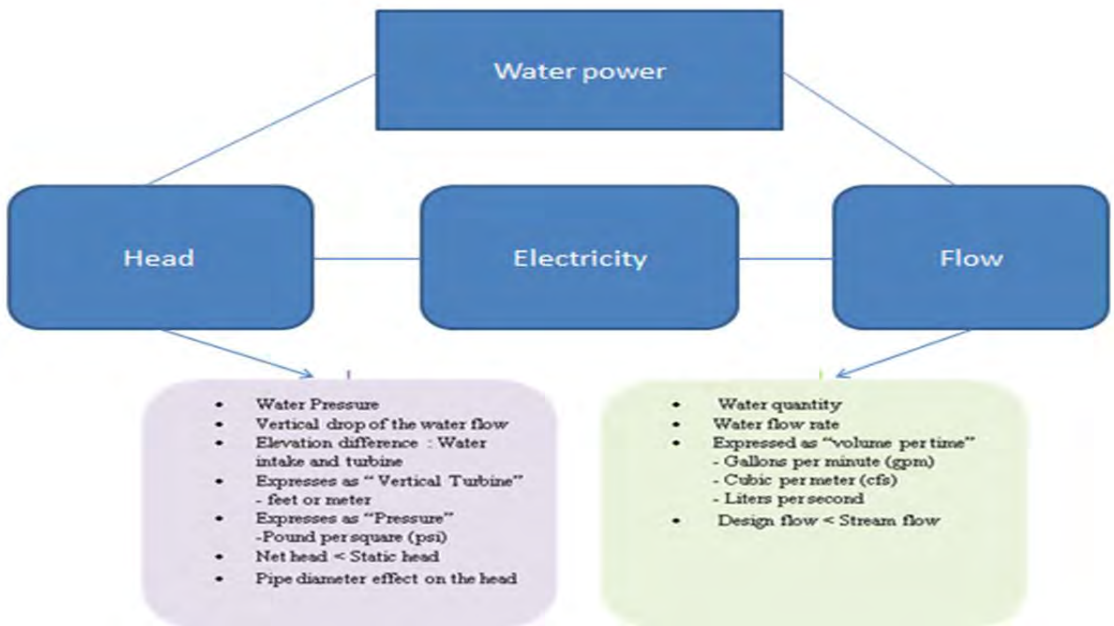

Figure 2.2: Head and flow in water power [4].

The head is referred to water pressure as the difference of water intake and the turbine and can be known as vertical distance. The pressure P, can be assumed as head and it is quantified in Newton's per square meter (N/m2) . Defining the pressure as the force F, that produced on per unit area A. Then, force is the product of mass, m (kg) times acceleration, a (m/s2). Acceleration from the water is equal to the gravitational. The following equation(2.1) till (2.7) are used to calculate the force, pressure and head [4].

The force can be calculated by using Newton's law:

$$F = ma \tag{2.1}$$

or

$$F = \rho V a \tag{2.2}$$

The acceleration of water equals to gravity constant as water move freely. So, the force calculation equals to:

$$F = \rho V g \tag{2.3}$$

Pressure can be calculate as:

$$P = F / A \quad (2.4)$$

or

$$P = \rho Vg / A \quad (2.5)$$

As volume is equal to height times by area, pressure can be calculated by using this formula:

$$P = \rho \, hg \quad (2.6)$$

Manipulate the equation parameter will give:

$$h = P / \rho \, g \quad (2.7)$$

Research state that low head site is not optimum enough as only small output power produce. Low head water resources need more water flow compared to high head. Table 2.1 show a classification of head according to class.

Table 2.1: Classification of hydropower according to head range[2].

Class	Head
Ultra Low Head	H < 3 meters
Low Head	3 meters < H < 30 meters
Medium Head	30 meters < H < 75 meters
High Head	H < 75 meters

2.4 Concept of turbine

This project is quite similar to the concept of water sprinkler that implanted in the turbine; the brief reaction turbine. This concept also have also been discussed by Abhijit Date and Aliakbar Akhbazadeh [8]. Generally, Such a turbine could performs while using pressurised water involving substantial along with minimal normal water. The water will go into the turbine by simply straight along with tangentially issue out of the turbine as well as could also be generated a new numerous presumptions inside investigation. Firstly the energy cannot be dissipated through viscosity and secondly, turbulence effect, compressible because water density (ρ) is considered constant and the air that can be compressed. The mechanical loses which is the bearing friction losses and wind age losses during the rotation rotor in generator should be ignored.

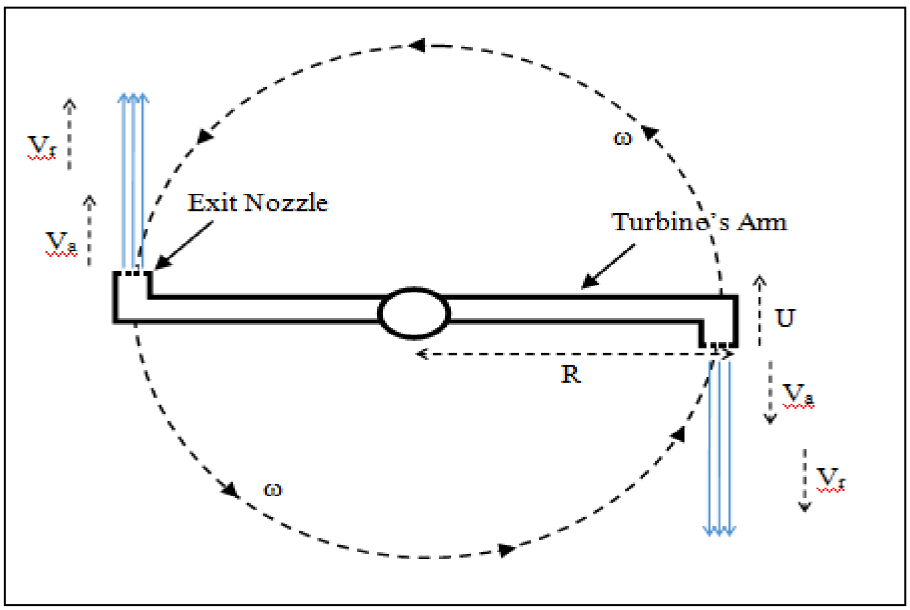

Figure 2.3: Rotor Schematic [9].

By referring figure 2.3, an appropriate equation which was obtained by the previous researcher [9] is applied as follows:

$$U = R\omega \tag{2.8}$$

$$V_a = V_r - U \tag{2.9}$$

Where V_r is the relative velocity of the water leaving the nozzle with respect to a stationary object in m/s and V_a is the absolute velocity of the water leaving the nozzle in m/s. U is the tangential angular. The kinetic energy of water according height of water reservoir H and centrifugal head H_c equation can be written as:

$$\frac{1}{2}\rho V_r^2 = \rho g(H - H_c) \tag{2.10}$$

So, from equation 2.9 and 2.10, , the equation for ideal relative velocity can be written as:

$$V_r = \sqrt{2gH + R^2}\omega^2 \tag{2.11}$$

In the equation 2.11, Vr is a water flowing out the nozzle of turbine in steady or rotary state. When the nozzle is at steady state, the head component will be equally to zero because there is no angular speed, ω, and the relative velocity, Vr can be state that it proportional to the square root of potential head, H.

The mass of water flow rate sprayed out the nozzle can be expressed as:

$$\dot{m} = \rho V_r A \tag{2.12}$$

The water exit nozzle area A in m^2 and density of water ρ in kg/m3.

Hence,

$$\dot{m} = \rho A\sqrt{2gH + R^2}\omega^2 \tag{2.13}$$

Torque is the product of mass flow rate, absolute velocity of water and radius of the turbine:

$$T = \dot{m}V_a R \tag{2.14}$$

The output power produced by the turbine:

$$\dot{W} = T\omega \tag{2.15}$$

Using the principle of conservation of energy, the total rate of hydraulic energy supplied at the inlet must be equal to the rate of mechanical work produced plus to the rate of loss of kinetic energy due to the absolute velocity of water that appear at the exiting water.

$$\dot{m}gH = \dot{W} + \frac{1}{2}\dot{m}V_a^2 \quad (2.16)$$

$$\dot{m}gH = \dot{W} + \frac{1}{2}\dot{m}V_a^2 + \frac{1}{2}\dot{m}V_r^2 \quad (2.17)$$

Finally, the efficiency of the system being able to convert potential energy to work can be written as:

$$\eta = \frac{\dot{W}}{\dot{m}gH} \quad (2.18)$$

By knowing the value of radius of the turbine R, gravity constant g, density of water ρ, angular velocity of turbine ω and height of water reservoir H, the parameters such as tangential angular U, absolute velocity of water leaving nozzle V_a, velocity of water leaving nozzle V_r, torque T, output power W and efficiency η can be determined and it is considered as the theoretical value.

The viscous loss, k-factor can be calculated by rewriting equation 2.13 as follows:

$$k = \frac{2gH + R^2\omega^2}{\left(\frac{\dot{m}}{\rho A}\right)^2} - 1 \quad (2.19)$$

The parameter in equation 2.19 can be experimentally obtained in order to get the value of k-factor. If the water supply held is constant, then the viscous losses will depending on the rotational speed and also water flow rate. The potential energy produce in the water from the reservoir or tank can be converted to mechanical power in order to get the efficiency η and also can be written as:

$$\eta = \frac{W}{\dot{m}gH} \quad (2.20)$$

The optimum diameter expression can be derived as:

$$\eta = \frac{R\omega}{gH}\left[-R\omega + \sqrt{\frac{1}{(1+k)}}\ x\ \sqrt{2gH + R^2\omega^2}\right] \quad (2.21)$$

By equating the differentials of turbine radius R equal to zero for the maximum efficiency condition dη/dR = 0 will get:

$$D_{opt} = 2\, R_{opt} = 2\, \frac{\sqrt{gH}}{\omega}\;\; x \sqrt{\left(\sqrt{\frac{1+k}{k}}\right) - 1} \qquad (2.22)$$

2.5 Revolution of Z-blade

The actual yearly worldwide hydropower manufacturing is extremely little when compared with the actual worldwide energy usage. Nevertheless, the officially exploitable hydro energy possible obtainable around the world is actually much more compared to is really already been utilized. Pico hydro is hydro generation system that can generate power up to 5 kW. Electric power generated is driven by the use of gravity to the water fall or water flow in hydro machine. The increased interest towards this system is due to the potential and capability of pico-hydro turbines to be alternative and ideal solutions to increase the demand for electrification in remote communities. Many investors have developed new water turbines with huge output amount of energy that can be produce at different level of water head with gain of high efficiencies. The classification of water turbine can be divided into two main categories according to their working principles which is reaction and impulse. The Z-blade turbine hydro generation is considered as a reaction turbine as it will be conduct the experimental testing by using low head water resource. The revolution of Z-blade turbine is organized according to timeline stated in figure 2.4.