CONCEPTUAL DESIGN OF MINI HYDRO TURBINE FOR RURAL AREA

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A report submitted
in fulfilment of the requirements for the
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DECLARATION

I declare that this project report entitled "Conceptual Design Of Mini Hydro Turbine For Rural Area" is the result of my own work except as cited in the references.

Signature :

Name : WONG CHU HING

Date : 18 JUN 2021

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature : ....

Name of Supervisor : DR. MASJURI BIN MUSA@OTHMAN

Date : 15 JANUARY 2021

DEDICATION

To my beloved father, mother and siblings for the endless support.

ABSTRACT

Turbines are used for exploiting water energy to gain useful energy. Mini hydropower can offer a continuous electricity to a rural area if it is well designed. Mini hydropower offers better opportunity to rural area in terms of electrification. There are a lot of potential for hydro in Malaysia where the availability of rivers already contributes or generates electricity supply in rural areas. In Malaysia, there are still a lot of places like Sabah and Sarawak are still having lower electricity coverage which is at 77% and 67% respectively. In this report, the mechanical design of the hydro turbine will be focused. The conceptual design of mini hydro turbine will be fully developed and elaborated according to the PSM guidelines. There were several studies like experiments and numerical test were done for searching the optimum designs or the most efficient geometry. The parameters like angle, numbers of blades and patterns of blades will be varied with different designs. Then, the simulation of flow velocity which is computational fluid dynamics (CFD) will be carried out to know the behavior of water flows. The most important findings like power output or the highest efficiency will be discussed and constructed through charts and tables. The best design will be proposed in the end of this project.

ABSTRAK

Turbin mesti digunakan untuk mengeksploitasi tenaga air menjadi tenaga berguna. Tenaga hidro mini dapat menawarkan elektrik berterusan ke kawasan luar bandar jika dirancang dengan baik. Tenaga hidro mini menawarkan peluang yang lebih baik ke kawasan luar bandar dari segi elektrik. Terdapat banyak potensi hidro di Malaysia dan ketersediaan sungai sudah menyumbang atau menjana bekalan elektrik di kawasan luar bandar. Di Malaysia, masih banyak tempat seperti Sabah dan Sarawak yang tentunya liputan elektrik lebih rendah iaitu pada 77% dan 67%. Reka bentuk mekanikal turbin hidro akan difokuskan di dalam laporan ini. Terdapat beberapa kajian seperti eksperimen dan ujian berangka dilakukan untuk memeriksa untuk mendapatkan reka bentuk optimum atau geometri dengan kecekapan terbaik. Reka bentuk konsep turbin hidro mini akan dikembangkan sepenuhnya dan ditulis mengikut garis panduan PSM. Parameter seperti sudut, bilangan bilah dan corak bilah akan berbeza dengan reka bentuk yang berbeza. Kemudian, simulasi halaju aliran seperti Computational Fluid Dynamics (CFD) *akan dilakukan untuk mengetahui tingkah laku aliran air. Kuasa paling tinggi atau kecekapan tertinggi akan dibincangkan dan dibina melalui carta dan jadual. Reka bentuk terbaik akan dicadangkan pada akhir projek ini.*

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Million thanks to Universiti Teknikal Malaysia Melaka (UTeM) for giving me a chance to participate and to gain experience in handling a final year project. Furthermore, I would like to thank all my friends for helping and giving me pieces of advising throughout the completion of this final year project.

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α: angle between the velocity of water and the tangent direction at the inlet impeller (°)

D_1 and D_2: outer and inner diameters of the impellers (m)

β_1 and β_2: each blade with respect to the tangent direction respectively at the outer and the inner diameters (°)

λ: angle of the arc available for the discharge inlet along the impeller outer circumference (°)

B: nozzle width (m)

W: impeller width (m)

P_t: Power of turbine (W)

P_{in}: input power (W)

η: Efficiency (%)

ρ: Density of fluid (kg/m^3)

H: Head(m)

S_0: Nozzle height(m)

N_b: Number of blades

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

A mini hydro power is a type of renewable energy by using water. Hydro power can produce power from 100 kW to 500 kW of electricity using the natural flow of water as well as Head. This installation normally can provide power to the long house, rural area, small community as long as there are rivers or waterfall locate over there. There are a lot of installations and different designs all around the world but all of them provide an economical source of energy without the use of fuel.

There are two indispensable parameters require in selecting the place to install the hydro system. The first one will be the available head and the flow rate of the water. The available head is defined as the vertical distance that waterfalls. However, the head also can be defined into two which are gross head and net head. The gross head of water is defined as the absolute vertical distance between the point at which the water imparts onto the turbine and the points of entry of the intake system. In the other hand, the net head is defined as the gross head minus all pipe losses due to friction and turbulence and it is used to calculate the available power capacity of the water resource. The water flow rate is the quantity of water flow in cubic meter per second. The higher each of these are, the more power can be generated by the turbine. So, we can say that both of the head and the water flow rate are very important in determining the power output as well as efficiency.

The sizes of hydropower scheme normally categories start with Pico to Large. Pico hydro is the hydroelectric power generation of up to 5 kW. These generators normally produce a small amount of electricity and it only can be used in small, remote communities. Micro hydro is the hydroelectric power that can generate from 5 kW to 100 kW of electricity by using the water natural flow. This type of hydroelectric power generation opens up new chances for some isolated places which in need of electricity. The remote areas can access lighting and communications with a small river needed. It can produce electricity for homes, schools, shops and other facilities like government facilities.

For the size scheme from micro to large, the term used are varies considerably around the world, but normally mini hydro power is the installations of between 100 kW to 500kW capacities. The Table 1 below is used for descripting the rough installations in a range of capacities according to the size scheme.

Table 1: The Size of Hydropower Scheme (Balat, 2006)

Size Class	**Range**
Micro	< 100 kW
Mini	100 – 500 kW
Small	500 kw – 50 MW
Large	> 50 MW

Last but not least, mini hydropower can give opportunity to support rural for expanding their electrification. Mini hydro also gives capacity support of the grid. The potential for constructing the small hydro in Malaysia is very huge. For example, Perting Mini Hydropower plant is one of the mini hydro power projects at Bentong, Pahang. Small hydropower is a good alternative to conventional electricity generation, it provides efficient electricity in rural areas. In Malaysia, there are a lot of hill and rivers, so it offers many potential sites for run-of-river small hydropower.

1.2 PROBLEM STATEMENT

In the rural area, there always have a need of electricity. The demand for electricity is increasing. Because of the nature of hydropower and its economic, the hydro power is suitable to be one of the sources to get electricity. Settlements at the rural or off-grid area are mostly stay beside the river for ease of their daily life in many sectors. So, the most effective manner to address these needs is utilizing the locally available renewable energy which is hydro energy.

The hydroelectric power plant is a renewable energy which has high efficiency, by far the best of all energy technologies. But the problems are how do we make sure our designed turbine can contribute an optimum efficiency? The general concept of a hydroelectric power plant to convert the kinetic energy as well as potential energy of the water moving with certain momentum into a usable form of electricity. Hydro power projects involve in many considerations at different implementation of the project are necessary. The ability to predict the efficiency, workable, functionable and even know the behavior of the product designed. For the cost effective and efficient of project we need to study the optimal design of the turbine.

1.3 OBJECTIVE

The objectives of this project are as follows:

1. To design a conceptual hydro power turbine which can produce power output up to 100 kW which up to 50 households and suitable for the rural area.
2. To design a high efficiency hydro power turbine more than 80% in term of power.

1.4 SCOPE OF PROJECT

The scopes of this project are:

1. Only mechanical design of the hydropower turbine presented in this report.

a. Identify the flow and shaft output generated of cross flow turbine using the Computational Fluid Dynamics (CFD) analysis of designed turbine in ANSYS.

2. Study the efficiency of the cross flow hydro turbine (CFT).
3. The parameters focused are number of blades, inlet blade angle and pattern of blades. The 3D solid modeling of the CFT will be conducted in SOLIDWORKS.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

When rainwater falls to the surface of earth, it possesses a type of energy in terms of potential. This energy will change to kinetic energy and bring all the water to the sea or ocean. If at a specific place which appreciable in vertical height, the water can be fall down. As the water fall with a height, the kinetic energy will be converted from the potential energy. Then, the kinetic energy also will convert to mechanical energy which is rotating the turbine runner of the hydropower plant. This mechanical energy which generated by the turbine is coupled to electric generator. Lastly, the electricity will be produced by the generator.

2.2 PART 1: THEORITICAL EXPLAIN ON HYDRO TURBINES

2.2.1 DIFFICULTY OF REMOTE SETTLEMENTS

Rural areas in many parts of the world are undergoing changes in response to population mobility and a growing awareness of ways in which better qualities of life may be achieved. Malaysia has experienced relatively rapid improvements in wellbeing in recent decades. Increasing population and many places of the world are improving rapidly. Remote settlements in the rural areas need to change their life to better qualities. Malaysia has made good improvements in recent decades especially increasing the electrification. Unfortunately, the development of electrification in rural area still in progress.

Peninsular Malaysia has more than 90% of electrification but for Sabah and Sarawak, the electrification rates are decidedly lower which is at 77% and 67% respectively. Remote areas are very difficult to access with transportation with no proper road access. So, this problem makes it difficult to install on-grid power generation. During the period from 2001-2005, the rural electrification programs, especially in Sabah and Sarawak, enhanced. These involve grid extension and the provision of stand-alone system generators comprising solar photovoltaic, mini-hydro, and hybrid systems.

According to Dr Kuok in 2013, 40 sites were identified. Rural areas, the villages not connected to the State Grid, were surveyed for implementing hydropower. These villages are located in Bintulu, Sri Aman, Miri, Kapit, Sarikei and Betong. In 2010 Third international conference and exhibition on water resources and renewable energy development, the findings were presented. Most of the sites in Kapit Division is found that they had limited capacity for implementing hydropower. In contrast, the tributaries of Baram river, streams in Betong and Lubok Antu could generate about 50 kW to 200 kW. So, the rivers in the rural areas of the East Malaysia are capable and potential to access. Lastly, more studies need to be carried out to identify which types of the turbines are suitable to be used.

2.2.2 CONSTRUCTION OF THE HYDRO TURBINE SYSTEM

There are a lot of types of construction of hydropower but there are some essential features of it. The intake where water is diverted from the natural stream, river, or perhaps a waterfall is the most important criteria. The intake structure like catch box as indicated in Figure 1 is required to block all the unwanted objects like fish, rubbish and etc. Normally there will use screen of bars to keep out big objects.

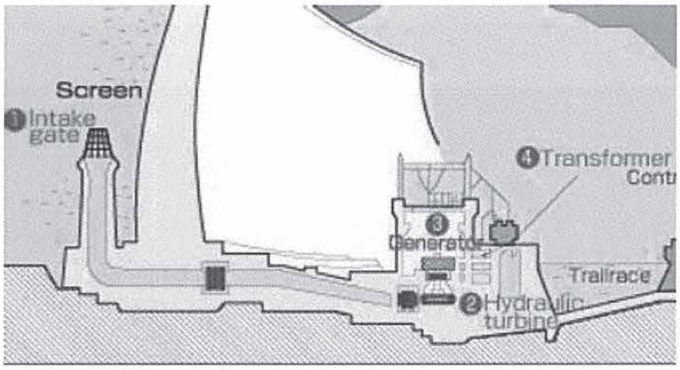

Figure 1: Example of The Intake (Tepco, 2021)

The intake is then brought to a forebay. The forebay is a type of sediment holding. It used to guide the water from the rivers or upstream to the penstocks or pipes. Sometimes it can block the water enter the penstock when undergo turbine maintenance or accident happen. It also can adjust the flow of the water to hydro power turbine.

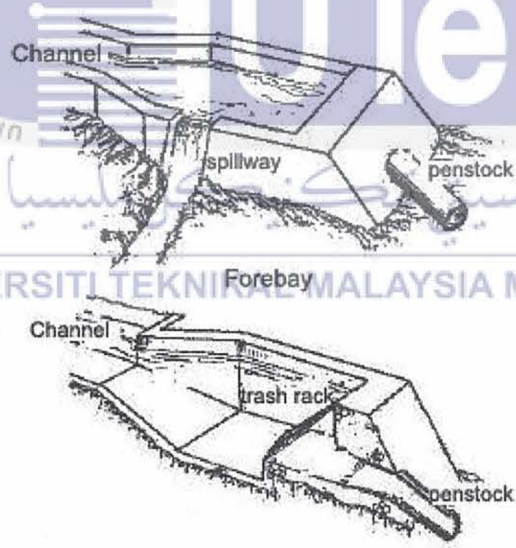

Figure 2: Example of Forebay (HS-Dynamic Energy, 2017)

Normally, there are penstock after the forebay. A penstock is a a gate that control the water flow. It also navigates the flow of the water to the turbine. The penstock builds up pressure vertically from the upstream to the turbine as shown Figure 3.

Figure 3: Example of Penstock (Jordan, 2018)

A controlling valve is used to regulate the speed of the turbine and flow of the water. The turbine converts the water energy to mechanical energy with the aid of pressure head and the volume flow rate. Figure 4 shows the example construction of the hydroelectric power.

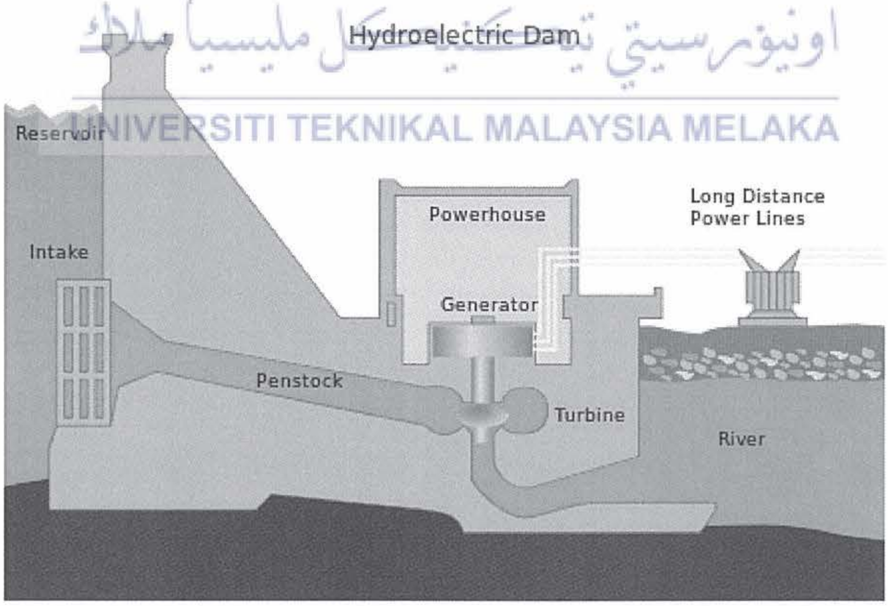

Figure 4: Construction of The Hydroelectric Power (Jordan, 2018)

The powerhouse is a place that we put all the stuff here. For example, the equipment and the control room normally locate here. The powerhouse is the 'brain of the human body'. We normally carried out all the monitor and control here. The turbine and generator are located at the powerhouse. So, if any maintenance on the turbine or generator will be more easily. Powerhouse will receive the water from a dam or reservoir through a pipe which is called as penstock.

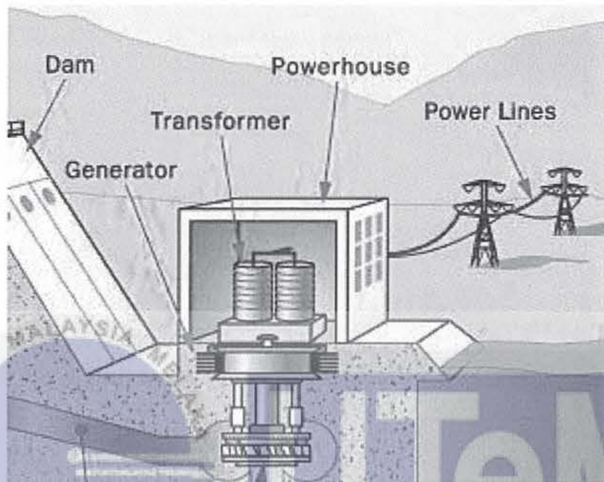

Figure 5: Example of Powerhouse (Bonsor, 2020)

For the downstream or the Outlet, there are the place that the flowing water ejected out from the hydro turbine. Normally the water will be ejected to the river or lake downstream.

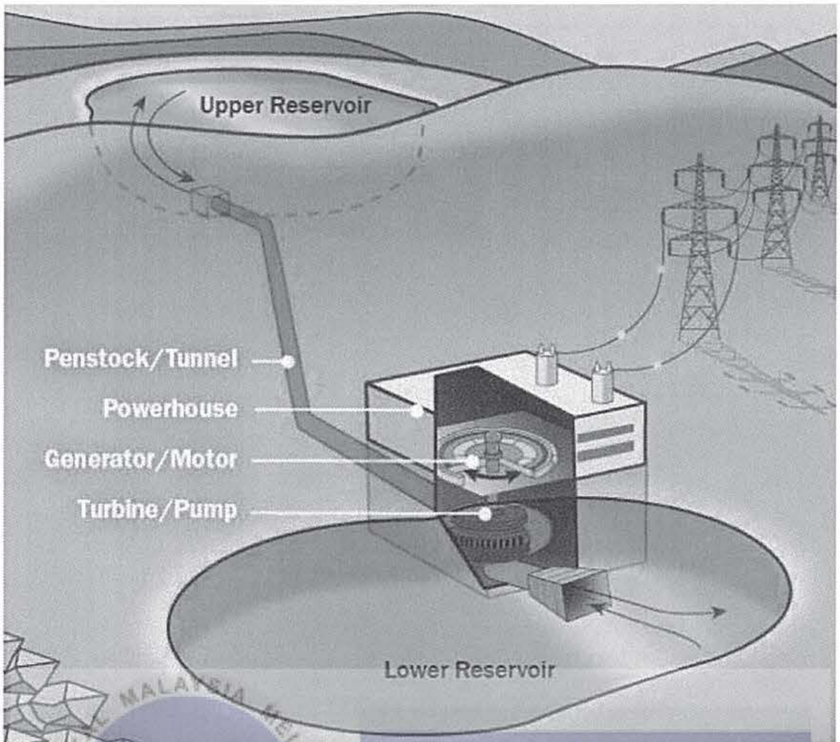

Figure 6: Example of Downstream Lake or Lower Reservoir (Erin, 2019)

2.2.3 DEFINITION OF HEAD

There are few types of head especially net head and gross head. The net head, or some time call as effective head, is the pressure available for power generation but it is in terms of head and the unit is meter. It is a type of gross head with difference between the water level at the forebay and the water level at the outlet. This is normally used in calculation for finding the power input of the system. The hydraulic losses need to be encountered it may vary for different material used in the penstock. The losses also counted in finding the efficiency of turbine.

While the gross head is the difference in elevation between the water levels of the forebay and the tailrace. Normally, the net head is less than the gross head due to the minor losses, h_f in pipe and some pressure losses. We can simply see clearly from Figure 7, the Gross Head, H_g is the head difference from upper stream of the water level (Head Race) to the bottom stream of the water level (Tail Race).