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LOW CURRENT TIDAL STREAM TURBINE FOR SARAWAK TIDAL STREAM APPLICATION

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LOW CURRENT TIDAL STREAM TURBINE FOR SARAWAK TIDAL STREAM APPLICATION

LOYRITA DULLING ANAK PANTAU

A dissertation submitted in partial fulfillment

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To my beloved family and friends

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ABSTRACT

Nowadays, tidal stream energy has become a viable choice of generating electricity in many countries. It is because the tidal stream energy are predictable and a reliable source of generating electricity as it is depend on the gravitational attraction between the Earth, the Sun and the Moon. The venture into this clean energy production is a practical choice. It is in enhancing energy security in Malaysia due to nature of the tidal stream technology require less construction and environmental effects. In this thesis, the aim is to design a low current tidal stream turbine for Sarawak tidal stream application. The low current tidal stream turbine based on the hybrid turbine of four blades Darrieus turbine (lift type), and 2 paddles of Savonius turbine (drag type) as the startup turbine. The hybrid turbine of 1 m height has a better starting torque and power output compare to any tidal stream turbine that operate by a single turbine in a low current tidal stream condition. The details designing of the turbine are discussed in this thesis by using Off Kuala Igan tidal stream data to design the suitable cut-in speed for the turbine in low tidal current condition. One unit of the turbine is able to produce daily energy of about 3.6 KWh (3669Wh) at low tidal stream speed of 1 m/s. The arraying of the tidal turbines to few units according to the available space without arising conflict with other sea users is possible in order to increase the power extraction and by deploying the turbine at higher tidal stream speed. The electric generation can be stand-alone power system for more decentralized future power system or the power system also can be synchronized with grid by exporting the surplus energy back to grid.

ABSTRAK

Pada masa kini, aliran tenaga pasang surut (tenaga kinetik dalam air laut) telah menjadi pilihan yang berpotensi untuk menjana elektrik di kebanyak negara. Hal ini demikian kerana aliran tenaga pasang surut boleh diramal dan dipercayai untuk menjana elektrik kerana tenaga tersebut bergantung kepada daya tarikan graviti antara Bumi, Matahari dan Bulan. Usaha mengeluarkan tenaga bersih ini adalah pilihan yang praktikal. Ini adalah untuk meningkatkan penjanaan tenaga di Malaysia berikutan sifat teknologi tenaga kinetik dalam air laut ini memerlukan kurang pembinaan dan kesan terhadap alam sekitar. Dalam tesis ini, tujuan utama adalah untuk mereka bentuk turbin sesuai dengan keadaan laut di Sarawak. Turbin untuk laut kelajuan rendah ini berdasarkan empat bilah turbin Darrieus yang berasaskan daya angkat dan 2 rotor turbin Savonius (daya seretan) sebagai turbin untuk memulakan seluruh pergerakan turbin. Turbin hibrid dengan ketinggian 1 m ini mempunyai tork permulaan dan penjana kuasa yang lebih tinggi berbanding dengan mana-mana turbin yang beroperasi menggunakan sejenis turbin sahaja dalam keadaan air laut yang beasus rendah. Butir-butir bentuk turbin turut dibincangkan dalam tesis ini dengan menggunakan data kelajuan air laut diluar pantai Kuala Igan Sarawak untuk menentukan kelajuan air yang sesuai bagi mengerakan turbin pada permulaan. Satu unit turbin mampu menghasilkan tenaga harian kira-kira 3.6 KWj (3669Wj) pada aliran kelajuan serendah 1 m/s. Permasangan beberapa buah turbin ini boleh dilakukan mengikut ruang di atas permukaan laut yang ada tanpa timbul konflik dengan pengguna laut yang lain untuk meningkatkan pengeluaran kuasa electrik atau dengan meletakan turbin tersebut dalam arus yang lebih laju. Penjanaan elektrik boleh dibekalkan tanpa sambungan ke grid utama untuk sistem kuasa yang lebih tidak berpusatkan sambungan grid dimasa hadapan. Malah, sistem kuasa ini juga boleh disambungkan kepada grid dengan tujuan untuk mengeksport tenaga lebihan daripada sesuatu penggunaan kepada grid.

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LIST OF SYMBOLS

C_P	-	Power coefficient
λ	-	Tip speed ratio
C_{P_S}	-	coefficient of efficiency for the Savonius
λ_S	-	Savonius turbine tip speed ratio
W_d	-	Speed of the turbine in rad/s
R_d	-	Radius of the Darrieus turbine in meter
V	-	Tidal stream speed in m/s
C_{P_D}	-	Darrieus turbine coefficient of efficiency
λ_d	-	Darrieus turbine tip speed ratio
A_D	-	Darrieus turbine swept area
H_D	-	Darrieus turbine rotor height
D_D	-	Darrieus turbine rotor diameter
C	-	Chord length of airfoil
A_S	-	Savonius turbine swept area
H_S	-	Savonius turbine rotor height
D_S	-	Savonius turbine rotor diameter

LIST OF ABBREVIATIONS

Aquaret	-	Aquatic renewable energy technologies
OTEC		Ocean Thermal Energy Converter
TISEC	-	Tidal in-stream energy conversion
TSGs	-	Tidal stream generators
SI	-	Strategic initiative
MLLW	-	Mean lower low water
SMD	-	Sarawak marine department
SR-VACT	-	Self-rotating vertical axis current turbine
TSR	-	Tip speed ratio
HTS	-	Hydraulic transmission system
RPM	-	Rotation per minute
2D	-	Two dimensional
3D	-	Three dimensional
STST	-	Sarawak Tidal Stream Data
Q1	-	First quartile
Q2	-	Second quartile
Q3	-	Third quartile
Tg.	-	Tanjung
TAS	-	Tidal Acceleration Structure

CHAPTER 1

INTRODUCTION

1.1 Motivation of Project

1.1.1 Clean energy

Malaysia is one of the countries that signed the Paris Agreement on April 22, 2016 in New York that set the goal of limiting global warming to less than 2ºC than the pre-industrial levels after the 2015 United Nation Climate Change Conference. It is where Malaysia renewing the country commitment towards lessening the country carbon intensity by 40% in 2020. Hussain (2016) stated that venture into new technologies regarding with the clean energy is a good decision as the renewable energy able to gain greater popularity just in a matter of time. For instance the solar energy has gain popularity with Malaysia as the world's third largest producer of solar PV panel.

In Malaysia, the electricity demand increase by 4% annually from 2010 to 2014 and it is assumed to increase by 1.5 times; 150,000 GW h in 2030 (Department of Statistics Malaysia, 2015). Sim (2016) mentioned that opportunists are the one that taking the risk by considering renewable energy as an assets by exploring the markets and idea decentralized power system that reduce the dependency on fossil fuel.

1.1.2 Advantages of tidal stream energy

Lako (2010) mentioned that the marine energy technology have limited number of application and the commercial installation is still in early phase of development and most of it still under demonstration that make it costly but expected to reduce in term of cost by 2020. Lim and Koh (2009) stated that the tidal energy more reliable and predictable compare to wind and solar energy. DeGraaf and Mather (2010) said that the tidal current can be predicted up to one hundred year in advance. Besides the power density of ocean is about 832 times greater than air which allows smaller flow of velocity yield an equal energy to the wind energy that travel at much faster velocity.

Moreover, the Earth's tides are caused by the tidal forces due to gravitational interaction with the Moon and Sun. Thus, the Earth's rotation that causes the tidal power is practically inexhaustible and identified as renewable energy (Lim & Koh, 2009). Sornes (2010) mentioned that the used of river or stream as a natural power of generating electricity has gains many interest since long time ago. Mehmood, Liang and Khan (2012) stated that the regulator play main role in enforcement of emission regulations that help to promote the ocean energy technology. For example, Liu et al. (2011) stated that energy laws in China had promoted tidal current energy as the main alternative and as the tidal current energy have high predictability, regularity, and compatible with environment.

Although tidal stream generator generate much less power than tidal barrage technology but the tidal stream technology is favorable as it is much more economically feasible due to less construction and reduce environmental impact (Lim & Koh, 2009). Meanwhile, Mehmood et al. (2012) stated that the technology is developing at fast pace although it is a quite new technology.

Furthermore, Mehmood et al. (2012) explained that tidal stream technology cause less threat to marine life for using slow spinning turbine compared to tidal barrage that disrupt migration of fish up rivers from the sea. Besides, the small application of tidal stream technology can be expanded when improvise technology are available due to the modularity characteristics of the technology. Liu et al, (2011) also mentioned that the tidal current energy is an effective solution to energy shortage and environmental pollution.

1.2 Background of Project

1.2.1 Tidal stream turbine technology history

In the early eight century, tidal energy is harness by using water wheel to mill grain and flour production when the Spanish, French and British built tidal storage ponds or known as tidal barrage where the tidal current flow through the sluice gates and closes during high tides to contain the water and the water then released to the ocean through water wheel to mill the grain (Lim & Koh, 2009).

1.2.2 Type of ocean energy

Tides are one of the ocean energy which possesses kinetic energy and potential energy. Others types of ocean energy are waves contain kinetic and potential energy, salinity gradient has chemical energy, and Ocean Thermal Energy Converter (OTEC) consist of heat energy (Mehmood et al., 2012). Each of the ocean energy sources has different working principle. Generally, tides are different between high and low tide, current or tidal stream is the horizontal movement of current due to current itself, wind, temperature and salinity differences, waves are energy created by wind currents passing over open water, salinity gradient is the energy due to different concentration of seawater and a river flows, and OTEC is the technology utilize heat engine that depend on the temperature different between cold and hot water to increase the engine efficiency (Mehmood et al., 2012).

1.2.3 Tidal technology harvester

Tidal energy technologies can be categories into three major types which are barrage tidal power, tidal stream system and tidal lagoons (Lim & Koh, 2009). Sornes (2010) also state that tidal currents and river streams are the two main sources for power generation by hydrokinetic device. In this study, tidal stream system technology will be the focus.

1.2.4 General review of tidal stream turbine

The tidal stream system is known as tidal in-stream energy conversion (TISEC) devices. TISEC devices are also known as tidal stream generators (TSGs) or called as Tidal Energy Converters are used to exact the kinetic energy from the fast flowing current site. Besides, the term tidal current or tidal stream will be used to expressing the tidal stream speed in this study. Mehmood et al. (2012) explained that tidal current is horizontal movement of the kinetic energy of water while the tidal range represents the potential energy. The tidal stream turbine can be place at harbors and lagoons.

1.2.5 Tidal stream energy extraction principles

Generally, the tidal stream kinetic energy is extracted from the current by flowing through or imparting the flow energy into the mechanical motion of a rotor blades or known as prime mover where the mechanical motion are converted into electrical energy by means of power train such as generator that is rotated as it is connected to the rotor by gearbox. The gearbox is the speed controller that converts the low rotational speed of the turbine shaft to higher speed of the generator shaft. Moreover, in order to control speed of the turbine blades at a certain cut out speed the braking system is needed. It is by using gearbox that reducing the torque to avoid damage of to the rotor along. The electrical output from the device is to be conditioned in order to make it compliant with the grid code regulation. Then the electricity generated is transport to the land through transmission cable. The transmission process is known as power take-off system where the electrical power and control system, and submarine cable feed into the onshore grid connection point if available.

The entire life cycle of tidal stream power scheme involve design and planning, construction and installation, operation and maintenance, and decommissioning (Aquaret, 2008).

1.2.6 TISEC device general selection factors

DeGraaf and Mather (2010) explained that there are quite number of TISEC device in different stages of development which differ in their design such as number and shape of rotor blades, and distribution of rotor at the hub. Besides, it also can be different in the way they are anchor and alignment mechanism it have.

The tidal resource is greatly site specific (Strategic Initiative for Ocean Energy (SI Ocean Energy), 2012), the selected TISEC device need to fit the environment of the potential site. Generally, the site influence which design of turbine should be used for the site (DeGraaf & Mather, 2010). Thus, it can offset the installation and maintenance costs by producing an ample amount of energy to the power grid. Besides, tidal stream generator needs to fit with the activities at the potential sites such as shipping so that it existing does not interrupt and raise another problem to the area. Thus, the anchoring techniques propose for the TISEC device need to be balance between the easy accesses for the device for maintenance while weighting it with the surrounding business.

Besides, the parameters of the potential site are important to choose the TISEC device. For example, the parameters are average of tidal stream in meter per second, current direction and water depth of the potential site for enough turbine deployment clearance on that site. The geometry of the potential site is also taken into consideration to propose the suitable anchoring methods for the location such as the seabed roughness. Aquaret (2008) said that resources such as tidal climate, rotor blades and power take-off system are the key factors that influence the performance of the TISEC device.

1.3 Problem statement

Nowadays, many countries had implemented the idea of energy extraction from tidal stream. However, most of the tidal stream technologies are big in size and suitable for tidal stream speed of 1.5 m/s and above. The technology does not suit Malaysia tidal stream condition particularly Sarawak with low current condition. The usage of the tidal stream harvester is essential in Sarawak to increase the area of electrification and boost the socioeconomic for the area with difficulty to be connected to main grid. There are few work have been done to design suitable turbine for Malaysia tidal stream condition. In this thesis, the aim is to design a suitable low current tidal stream turbine according to the Sarawak tidal stream condition which mostly along the coastline area.

What type and design of tidal stream turbine is suitable to harvest the low current tidal stream condition for Sarawak tidal stream application by using tidal stream data from Off Kuala Igan Sarawak to design the turbine? Besides, the power output from the turbine also need to be calculate to access the feasibility of the turbine installation in term of cost and along with how the electric power system can be used for place near grid and off-grid.

1.4 Objectives

There are few objectives of the project which are:

1. To study the type and design of the tidal stream turbine to harvest the low current tidal stream condition by using tidal stream data from Off Kuala Igan Sarawak
2. To determine the power output from the turbine
3. To identify the electrification purpose and overall electric power system for the turbine

1.5 Project Significant

The significant of this project are:

1. To drive the implementation of the renewable energy to another level in Malaysia by extracting tidal stream energy and moving toward additional sustainable power generation within the country
2. To compensate the usage of electricity and reduce dependency on non-renewable energy for electricity generation
3. Suitable to be adapt in off –grid location for rural electrification to enlarge the energy access when the grid connection is unfavorable option
4. The project can be a bench mark and case study to estimate the overall life cycle of tidal stream turbine for the improvement work of turbine
5. To create a job opportunity and expertise in the tidal stream turbine industry for bigger scale turbine implementation

1.6 Scopes of the project

The scopes of this project are to design the low current tidal stream turbine that suitable for Sarawak tidal stream application. The tidal stream analysis for one location is done for details understanding of the tidal stream condition. Next, the turbine is design by determination of the cut-in speed for the turbine at the very first place. It is to decide the proper configuration of the turbine sizing. Furthermore, the power output from the turbine is calculated according to few average tidal stream velocities. The purposes of the electrification along with the turbine electric power system are also discussed.

However the environmental effect on surrounding ecosystem or known as oceanic environment due to the installation of the tidal stream turbine over a complete active life cycle for a full scale models such migration and hunting pattern, water quality or the rate of pollution according to type of paint and coating used due to the necessary coatings and lubrications to control the natural occurring corrosion and fouling are not included in this scope of project.