TURBINE BLADE DESIGN FOR TIDAL BARRAGE SYSTEM AND SIMULINK MODEL IN ELECTRICITY GENERATION

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MASTER OF ENGINEERING (ELECTRICAL)

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SUPERVISOR’S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Engineering in Electrical.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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LIST OF SYMBOLS

E_p	-	Potential energy (J)
C_p	-	Power coefficient
λ	-	Tip speed ratio
g	-	Acceleration due to gravity (ms^{-2})
ρ	-	Density of the water (seawater is 1025 kgm^{-3})
A	-	The sweep area of the turbine (m^3)
h	-	Tide amplitude (m)
P	-	The power generated (W)
ξ	-	The turbine efficiency
V	-	The velocity of the flow (ms^{-1})
P_e	-	Electrical power (W)
T_e	-	Electrical torque (Nm)
T_m	-	Mechanical torque (Nm)
P	-	Number of poles pair
ω_r	-	Turbine rotor speed (rpm)
β	-	Viscous friction coefficient factor

LIST OF ABBREVIATIONS

CFD	-	Computational Fluid Dynamics
CFX	-	Computational Fluid Experts
IEA	-	International Energy Agency
TWh	-	Terawatt hour
MWatt	-	Megawatt hour
UMP	-	Universiti Malaysia Pahang
PMG	-	Permanent Magnet Generator
AC	-	Alternating Current
DC	-	Direct Current
CFS	-	Feet Per Second

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ABSTRAK

Tenaga pasang surut telah diiktiraf sebagai salah satu teknologi yang berpotensi untuk penjanaan elektrik masa depan kerana kebolehramalannya berbanding dengan sumber tenaga terputus-putus seperti solar dan angin. Walau bagaimanapun, tenaga pasang surut secara tradisinya telah terkenal sebagai teknologi yang memerlukan kajian menyeluruh untuk mengenal pasti tapak yang sesuai dan modal pendahuluan kerana melibatkan kos pembinaan yang tinggi. Kajian literatur mengenai perkara ini menunjukkan beberapa kajian yang sangat terhad telah dijalankan ke atas tenaga pasang surut disebabkan oleh keberkesanan kos untuk memulakan sistem tenaga pasang surut, terutama di negara-negara yang mempunyai tenaga air pasang yang lebih rendah seperti Malaysia. Penjanaan elektrik tenaga pasang surut bergantung sepenuhnya kepada reka bentuk bilah turbin yang sesuai kerana ia menentukan hasil keluaran kuasa output yang telah ditetapkan. Oleh itu, reka bentuk bilah turbin yang tidak betul akan membawa kepada kegagalan dalam penjanaan elektrik. Di samping itu, pemodelan sistem bilah pasang surut adalah penting untuk merealisasikan penjanaan elektrik yang betul. Kajian ini bertujuan untuk mereka-bentuk bilah turbin yang khusus untuk sistem pasang surut jenis Meal. Reka bentuk itu dibangunkan menggunakan SolidWorks. Selain itu, model Matlab Simulink dibangunkan untuk mewakili konfigurasi penjanaan elektrik untuk system pasang surut. Analisis daripada Jadual Pasang Surut 2014 yang dihasilkan oleh Pusat Hidrografi Nasional Malaysia menunjukkan bahawa tapak yang paling sesuai untuk memanfaatkan air terbuka tenaga pasang surut adalah Selangor, manakala Terengganu adalah tapak yang paling sesuai untuk memanfaatkan pemecah ombak tenaga pasang surut. Ini adalah kerana; lokasi Kuala Terengganu mempunyai pemecah ombak yang sedia ada. Dengan menggunakan pemecah ombak, tenaga pasang surut akan menjadi lebih terhad dan tepat. Oleh itu, output kuasa yang dihasilkan adalah lebih tinggi daripada dalam sistem air terbuka. Selain itu, kajian bilah juga dijalankan untuk menentukan reka bentuk bilah yang lebih baik dalam mengoptimumkan kecekapan tenaga pasang surut melalui pemecah ombak. Terdapat dua jenis bilah yang telah direka mengikut kesesuaian sistem yang digunakan untuk tenaga pasang surut: turbin heliks dan turbin bilah lurus. Reka bentuk ini telah dipilih untuk memudahkan pemasangan pada pemecah ombak sebagai empangan. Berdasarkan analisis yang dijalankan menggunakan CFD (Fluent), didapati bahawa turbin bilah lurus menghasilkan kuasa yang lebih tinggi berbanding turbin heliks. Ini membuktikan bahawa; turbin bilah lurus adalah reka bentuk yang terbaik untuk dilaksanakan pada pemecah ombak untuk sistem tenaga pasang surut yang menggunakan empangan di pantai timur Malaysia. Selain itu, dengan merujuk kepada simulasi Matlab yang telah dilakukan, kuasa keluaran bagi penjana elektrik adalah 2465.817 MWatt setahun. Kesimpulannya, sistem tenaga pasang surut akan dapat memanfaatkan kuasa yang tinggi dengan kepala air yang rendah di Malaysia.

ABSTRACT

Tidal energy has been recognized as one of the promising technologies for future electricity generation due to its predictability as compared to intermittent energy sources such as solar and wind energy. Nevertheless, tidal energy traditionally has been renowned as a technology that required extensive study to identify the suitable sites and upfront capital as it is very expensive to build. Literature review on the subject presented very limited studies that have been conducted on tidal energy mainly due to cost effectiveness to start up the tidal energy system, especially in countries that have lower energy tides such as Malaysia. Tidal scheme electricity generation depends entirely on the correct design of the turbine blade since it determines the expected output power. Therefore, improper design of the turbine blade will lead to failure in electricity generation. In addition, modelling of tidal blade system is crucial to realize the proper generation of electricity. The study aims to design turbine blade dedicated to tidal barrage system. The design was developed using SolidWorks. Consequently, a Matlab Simulink model is developed to represent the configuration of tidal electricity generation. Analysis of the 2014 Tides Table produced by the Malaysian National Hydrographic Centre suggests that the most suitable site for harnessing open-water tidal energy is Selangor, whereas Terengganu is the most suitable site for harnessing breakwater tidal energy. This is because Kuala Terengganu has an existing breakwater. By using breakwater, tidal energy will be more limited and precise. Therefore, the resulting power output is higher than in open water system. In addition, a study of blade is also conducted to determine which designs of the blade are better in optimizing tidal energy efficiency through the breakwater. There are two types of blades which have been designed according to the suitability of the system applied to the tidal barrage: helical turbine and straight blade turbine. These two designs were chosen for ease of installation on the breakwater as checkers. Based on the analysis carried out using CFD (Fluent), it was revealed that the straight blade turbine output power was higher than the helical turbine. This proves that straight blade turbine is the used at breakwater for tidal barrage system which uses a dam on the east coast of Malaysia. Furthermore, by referring to the Matlab Simulink model, the output power for electrical generator is 2465.817 MWatt per year. In conclusion, tidal barrage system would be able to harness the high power with the low head water in Malaysia.

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