TECHNO-ECONOMIC ANALYSIS OF OFFSHORE WIND/PHOTOVOLTAIC FARM IN MALAYSIA

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DEDICATION

Dedicate, in thankful appreciation for support, encourage and understandings

To

My supervisor Prof. Madya Ir. Ts. Dr. Lau Kwan Yiew

My beloved mother Zaharah Binti Ali and father Fazi Bin Mohad

To my spouse Shahirrul Haqim Bin Mailah

My sisters Noor Hazlina, Siti Bahiah and Rafidah

And all person who contribute to this project.

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ABSTRACT

-Malaysia targets to supply 20 percent of total electricity generation by 2025 from renewable energy sources. The existing renewable energy mix in Malaysia includes photovoltaic (PV), biomass, and small hydro. Like many other renewable sources, wind energy has been considered in Malaysia since the 1990s. This is because wind energy is well-known for its high efficiency and can be a major energy contributor to total renewable energy globally. However, the onshore wind energy speed in Malaysia is relatively low, thus restraining it from becoming one of the potential energy mix sources in Malaysia. Unlike onshore wind, offshore wind is very well known as having a higher average speed and as Malaysia is surrounded by the South China Sea, this raises its opportunity to harvest the energy from offshore wind sources. At present, there are limited studies regarding the potential use of offshore wind energy in Malaysia. Acknowledging many advantages of the hybrid wind energy system, this study is done to perform techno-economic analysis of the grid-connected offshore wind-PV hybrid system by using simulation software. This includes the design of the optimized offshore wind-PV hybrid system with minimum net present cost (NPC) and cost of energy (COE) based on Malaysia's average residence load and the sensitivity analysis of offshore wind-PV hybrid system based on variations in several key parameters. The area for offshore wind energy systems is selected by applying the system's constraints. Based on the constraints, there are four possible locations in Malaysia for harvesting the energy, with coordinates (2.36, 110.28) as Zone 1, (3.94, 103.75) as Zone 2, (5.73, 103.19) as Zone 3, and (6.57, 117.90) as Zone 4. The simulation is done by using HOMER software and the optimized sizing design is selected based on two factors which are the lowest NPC and COE value. The comparison between the zone's analysis results is done to know the factor that caused the difference in economic and system operation aspects. The sensitivity analysis is done to know the effect of three parameters which are load, interest rate, and net enrgy metering, NEM value on technical and/or economic aspects output of the system. The result demonstrates that all the parameters greatly impact the system's operation and cost. Thus, all parameters must be included in consideration of implementing the grid connected offshore wind turbine-PV farm in Malaysia

ABSTRAK

Malaysia mensasarkan untuk membekalkan sebanyak 20 peratus daripada jumlah penghasilan tenaga elektrik dari sumber tenaga yang boleh diperbaharui. Tenaga yang boleh diperbaharui yang sedia ada di Malaysia ialah tenaga solar, biomass dan air. Di Malaysia, tenaga angin telah dipertimbangkan sebagai sumber tenaga yang boleh diperbaharui sejak tahun 1990an. Ini kerana tenaga angin diketahui sebagai sumber tenaga yang mempunyai kecekapan yang tinggi dan menjadi penyumbang tenaga terbesar di peringkat global. Angin di luar pesisir mempunyai kelajuan purata yang tinggi dan disebabkan Malaysia dikelilingi oleh Laut China Selatan, ia meningkatkan peluang untuk menghasilkan tenaga dari sumber angin di luar pesisir. Kajian berkenaan tenaga angin luar pesisir di Malaysia adalah terhad sekarang. Kajian ini dilakukan untuk menganalisis sistem tenaga campuran angin luar pesisir dan solar yang bersambung ke grid secara tekno-ekonomi dengan menggunakan perisian simulasi. Ini termasuk untuk mereka bentuk tenaga angin luar pesisir dan solar yang optima dengan kos semasa bersih dan kos tenaga yang minima berdasarkan beban tenaga kediaman di Malaysia dan analisis kepekaan terhadap sistem ini berdasarkan beberapa parameter utama. Kawasan untuk sistem tenaga angin luar pesisir dipilih dengan mengambilkira kekangan sistem terhadap kawasan luar pesisir di Malaysia. Didapati terdapat empat kawasan yang berkemungkinan untuk menghasilkan tenaga ini iaitu koordinat (2.36, 110.28) sebagai Zone 1, (3.94, 103.75) sebagai Zone 2, (5.73, 103.19) sebagai Zone 3 and (6.57, 117.90) sebagai Zone 4. Simulasi dibuat dengan menggunakan perisian HOMER dan sistem yang optima dipilih berdasarkan dua factor iaitu nilai NPC dan COE yang terendah. Projek ini akan menentukan prestasi sistem campuran tenaga angin luar pesisir dan solar yang disambung ke grid dalam terma keberkesanan kos, kemampanan sistem dan kebolehlaksanaan begitu juga kesan beban tenaga, kadar bunga dan kadar NEM terhadap sistem ini. Perbandingan antara hasil analisis di antara keempat-empat zon dilakukan untuk mengetahui faktor yang menyebabkan perbezaan dalam aspek ekonomi dan operasi sistem. Analisis kepekaan dilakukan untuk mengetahui kesan tiga parameter iaitu beban tenaga, kadar bunga dan nilai NEM terhadap aspek teknikal dam ekonomi sistem ini. Hasil dari simulasi menunjukkan semua parameter ini memberi kesan yang besar terhdap sistem operasi dan kos. Oleh itu, ia patut diambilkira dalam pertimbangan untuk melaksanakan sistem angin luar pesisir dan PV yang disambung ke grid di Malaysia

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LIST OF ABBREVIATIONS

CC	-	Capital Cost
COE	-	Cost of Energy
CRF	-	Capital Recovery Factor
FiT	-	Feed in Tariff
HOMER	-	Hybrid Optimization Model for Electric Renewables
IRENA	-	International Renewable Energy Agency
LCOE	-	Levelised Cost of Energy
NEM	-	Net Energy Metering
NPC	-	Net Present Cost
NPV	-	Net Present Value
NREL	-	National Renewable Energy Laboratory's
O&M	-	Operation & Maintenance
PV	-	Photovoltaic
RE	-	Renewable energy
RM	-	Ringgit Malaysia
ROI	--	Return of Investment
SEDA	-	Sustainable Energy Development Agency
TNPC	-	Total Net Present Cost
USD	-	US Dollar
UTM	-	Universiti Teknologi Malaysia

CHAPTER 1

INTRODUCTION

1.1 Introduction

Energy plays a fundamental role in economic development of all countries. Each year, the world population increase and this affects the increase in energy consumption. As the current primary energy supply is from fossil fuel, this situation causes the rise in local pollution and global warming due to CO_2 emission. In addition, the critical depletion rate in fossil fuel sets a challenging situation in energy supply. Thus, alternatives energy such as solar photovoltaic, wind, biomass and hydro are the best solution to mitigate both environmental and fossil fuel depletion issues.

Malaysia's primary energy supply is mainly contributed by fossil fuel including petroleum, natural gas and coal and followed by renewable energy sources which are hydropower, biomass and solar energy. Even there is a significant difference between fossil fuel and renewable energy which is more than 85 percent, but still, there is a slight decrease in fossil percentage in the energy mix as being replaced by renewable energy from 1996 to 2016 [2]. This is due to Malaysia's effort on promoting sustainable energy in order to meet the energy demand at the same time minimizes the environmental impacts such as greenhouse gas emission and climate change. Renewable energy policy has been started from 2001 in 8th Malaysia Plan on introducing renewable energy as the fifth fuel. Starting from this, many policy and incentives were launched by government of Malaysia to promote renewable energy [30]. However, the renewable energy targets have not been achieved by current renewable energy sources. in addition, government of Malaysia continuously assessing in wind energy in order to include it into the energy policy.

1.2 Problem Statement

Wind energy is one of the renewable energy sources which is abundant and clean. Since the 1990s, many research works have been done in investigating the potential of wind energy in Malaysia [3]. In order to harvest wind energy, the area must have relatively high average wind speed which is more than the turbine cut-in speed which is typically 3 m/s as for rotating the wind turbine [4]. The average wind speed in Malaysia is under low category and only certain locations such as Mersing, Kudat, Langkawi and Tioman Island which have wind speed above 3 m/s for height above 30 m [5-11]. The analysis study of hybrid wind with other alternative energy sources shown that the cost of energy is lower at high potential locations that have high wind speed that is more than 3 m/s and more energy can be harvested from wind compare to PV for the same land area [12-17]. However, the energy that can be harvested from this high potential area cannot meet Malaysia's energy needs. Thus, since offshore wind typically has higher wind speed compared to the onshore, it has the possibility to be one of the renewable energy sources in Malaysia. Previous analysis study related to offshore wind energy in Malaysia reveals that this energy system can generate a lower cost of energy compared to onshore wind systems [18]. However, this study only analyses solely on offshore wind energy without considering any hybrid system which could have various advantages. It also only includes feed-in-tariff for economic and sensitivity analysis without considering green incentives offered by the government under MyHIJAU programme. This project is to fill the existing gap of the stated area regarding the offshore wind hybrid system which includes the current policy and incentives offered by the government

1.3 Objective

The objectives of this project are:

i. To evaluate the techno-economic performance of offshore wind/PV hybrid systems by using simulation software.
ii. To determine the optimized design of offshore wind/PV hybrid system with minimum net present cost (NPC) and cost of energy (COE) that can cover all or a part of the total Malaysia load.
iii. To perform the sensitivity analysis of offshore wind/PV hybrid systems based on variation in loads, interest rate and net energy metering rate.

1.4 Scope of Work

This research includes a detailed study of the offshore wind energy system in Malaysia. The South China Sea and Malacca Strait's wind characteristics were studied by using a relevant wind forecasting website to know the pattern of the wind speed and direction before deciding the best location for harvesting the wind energy. The PV system was then set up at the coast near the offshore wind system location which would require the coast solar radiation and clearness index data. HOMER Pro software will be used to simulate all the data to analyse the feasibility of offshore wind and PV hybrid systems in Malaysia. The cost analysis was performed under Malaysia circumstances which include the tax and currency exchange

1.5 Outcome

This work produces the following outcomes:

i. The energy analysis of offshore wind/PV hybrid systems based on the selected technical aspects.
ii. The techno economic analysis of offshore wind/PV hybrid systems based on current Malaysia policies and incentives.
iii. The sensitivity analysis of the cost of energy of the hybrid system after variation of loads, interest rate and NEM.

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