UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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TAJUK: **Design and Analysis of Offshore Wind Power Platform**

SESI PENGAJIAN: 2009/10 Semester 2

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Design and Analysis of Offshore Wind Power Platform

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Design) with Honours.

by

KHOR HAN WEI

FACULTY OF MANUFACTURING ENGINEERING

2010

DECLARATION

I hereby, declare this Final Year Project Report entitled "Design and Analysis of Offshore Wind Power Floating Platform." is the results of my own research except as cited in the references.

Signature	:	…………………………………
Author"s Name	:	KHOR HAN WEI
Date	:	9th APR 2010

APPROVAL

Theis report submitted to the Faculty of Manufacturing Engineering of UTeM has been accepted as partial fulfillment of the requirement for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) with Honours. The members of the supervisory committee are as follows:

………………………………………………

Supervisor: Mr. Taufik.

Date: ....

Stamp: ....

ABSTRACT

The title of this project is Design and Analysis of Offshore Wind Turbine. The objective of this project is to gather the design data to competently design an offshore wind turbine, which is composed of three main structures comprising of the rotor/blades, the tower nacelle and finally the supporting structure. This project is important because wind energy is the fastest growing renewable energy in the world and major gains in terms of energy generation are achievable when turbines are moved offshore. For the purposes of this Bachelor project, in-depth analysis of rotor/blades will not be the focus. Design will focus on the nacelle and supporting structure. The completed final design is analyzed using commercial finite-element modeling tool ANSYS to obtain the structure‟s response towards loading conditions and to ensure it complies with guidelines laid out by classification authority Det Norske Veritas. Finally, a model of the structure will be fabricated using Rapid-Prototype technology.

Keywords: Offshore Wind Turbine, Design and Analysis, Computer Aided Design, Computer Aided Engineering, Finite Element Analysis, ANSYS, Foundation, Nacelle, Computational Fluid Dynamics.

ABSTRAK

Tajuk projek ini adalah kajian tentang “Design and Analysis of Offshore Wind Turbine”. Projek ini pada asasnya adalah untuk mentakrif pengesahan rekabentuk pada “Offshore Wind Turbine” dan bermula dengan kajian untuk mendapatkan data rekabentuk untuk struktur yang sedia ada. Struktur terdiri daripada tiga komponen utama iaitu bilah mata turbin, “nacelle” dan juga struktur penyokong. Projek ini penting kerana kuasa udara merupakan bidang yang sedang berkembang dengan pesat antara kuasa alternatif dan perkembangan besar dari segi pengumpulan kuasa dijangka apabila turbin ini didirikan luar laut. Untuk objektif projek sarjana muda ini, bilah mata turbin tidak akan menjadi fokus, sebaliknya fokus akan kepada struktur penyokong dan “nacelle”. Rekabentuk akhir akan dianalisis mengunakan software ANSYS untuk menentukan respon struktur terhadap muatan yang dikenakan. Ini juga untuk menentukan bahawa struktur mengikuti piawaian yang diluluskan oleh Det Norske Veritas. Pada akhir projek, suatu modal Rapid Prototype akan dihasilkan.

ACKNOWLEDGEMENT

First and foremost, I would like to take this opportunity to express my gratitude and appreciation to my knowledgeable supervisor, Mr. Taufik, for his full guidance and the continuous support and help given to me allowing me to accomplish this project. His willingness and eagerness to assist my project throughout these few months have been invaluable and very timely.

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List of Acronyms and Abbreviations

CAD	-	Computer Aided Design
CAE	-	Computer Aided Engineering
CNC	-	Computer Numerical Control
DNV	-	Det Norske Veritas
EPA	-	Environmental Protection Agency
IEO	-	International Energy Outlook
JONSWAP	-	Joint North Sea Wave Observation Program
NREL	-	National Renewable Energy Laboratory
OWT	-	Offshore Wind Turbine
RP	-	Rapid Prototyping
TLP	-	Tension Leg Platform

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Chapter 1

INTRODUCTION

The energy industry have been experiencing a period of massive growth as consumption of energy rose and are rising higher, driven mostly by developments in industrial growth in countries such as China and India and also developed countries such as Germany and the United States.

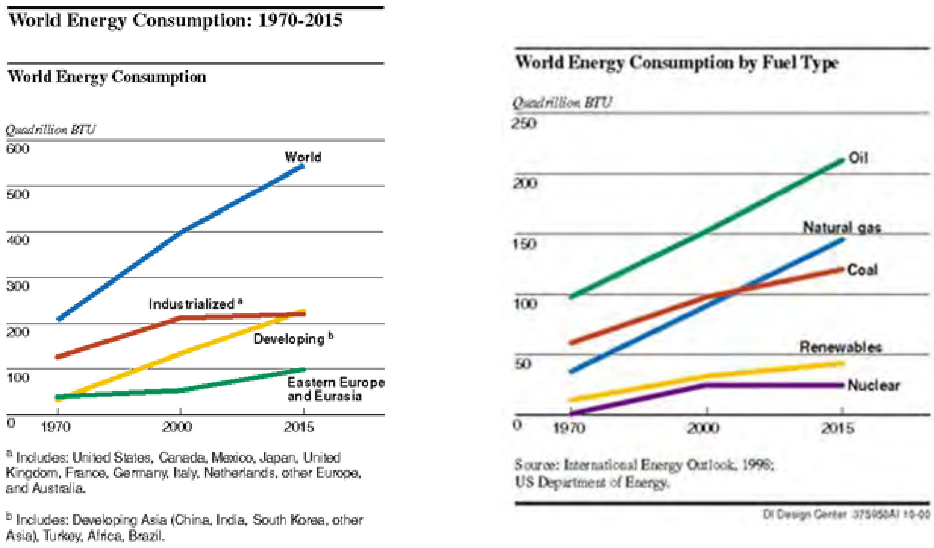

Figure 1-1: Energy consumption by country and fuel type 1998, USDOE (2009)

The chart to the left is sourced from the US Department of Energy and shows the trend of energy consumption as a linear growth. Industrial and developed countries lead the consumption but are expected to be overtaken by developing countries by 2015.

As for the energy by consumption type, it is obvious that fossil fuels, which are oil, natural gas and coal contribute some 80% of the total energy requirements of our world and although it is expected to grow linearly, production is a different matter as fossil fuels are getting more and more scarce.

Russian Prime Minister Vladimir Putin recently announced that the era of cheap energy is over and that the rising cost of extracting energy means the price of energy will only continue to increase. This was demonstrated briefly in mid-July of 2008 when oil prices hit $147 per barrel, the highest on record since oil was first drilled.

The petroleum problem, or as President Bush calls it the „addiction to petroleum" is becoming a problem as economies become dependent on oil producing countries supplying them with enough cheap energy to keep their economies growing. However the price spike showed that this dependence can have serious consequences.

Based on the historical figures, the latest International Energy Outlook released by the US Department of Energy shows a prediction of the price of oil rising steadily up to $130 by 2030.

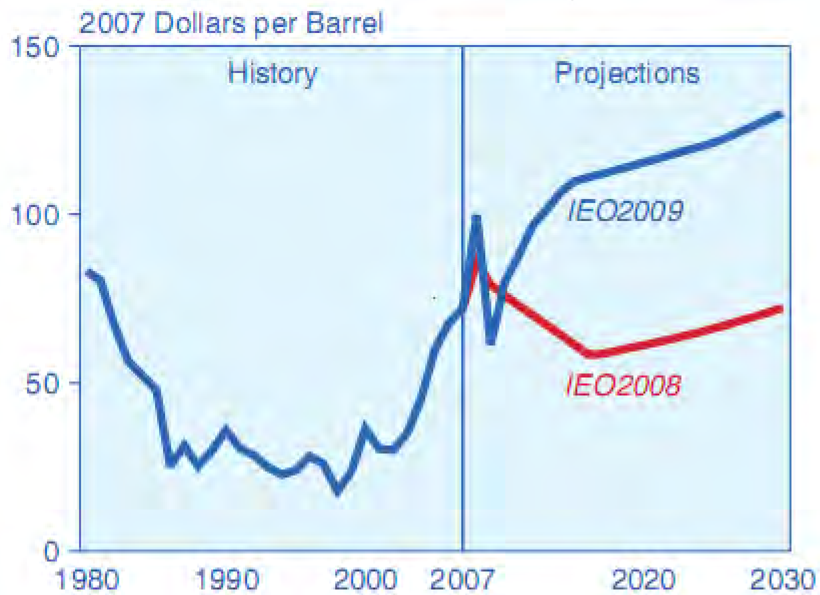

Figure 1-2: Historical and projected price of oil in US Dollars per barrel, USDOE (2009)

The revision from IEO2008 to IEO2009 is caused mainly by the unexpected recovery of oil prices and a faster-than-expected recovery of the global economy which saw oil prices swing back to the high $60s to low $70s.

The demand of energy will see renewable energy play an increasingly important role as fossil fuels become more and more expensive and harder to justify in expenses. It is expected that wind energy will contribute 1.1 trillion kilowatt-hours of the total 3.3 trillion kilowatt-hours of renewable energy predicted to be supplied by 2030. Furthermore, it is expected that only solar and wind can provide economical alternative energy sources, as other exotic renewable energy sources remain expensive and unproven.

Thus it is apparent that wind and solar are going to be the focus for future engineering efforts as we try to cope with this thirst for energy. Solar energy is expected to become dominant as Arab countries with vast swaths deserts have already started investigating the prospect of generating solar power to continue developing their countries.

For wind energy, the future lies in developing offshore wind turbines that are capable of harnessing the much higher wind speeds available offshore while avoiding the problem of skyline pollution. A more detailed investigation of the current and future wind energy outlook will be presented in the next section.

1.1 BACKGROUND

Wind power have been present in the history of man helping to do work such as moving ships using sails and also with milling grains to create flour. It is also harnessed for entertainment (kites) as well as providing a means for moving water using water mills. All these are early examples of humanity harnessing the natural power of wind in order to do work.

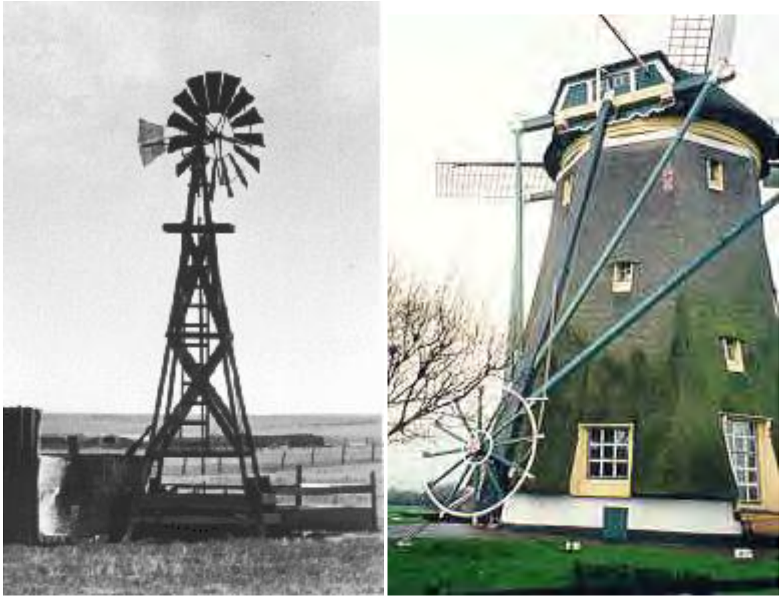

Figure 1-3: Early examples of windmills which harness wind energy and converts it into mechanical motion/energy. Picture courtesy of Darrel Dodge, Illustrated History of Wind Energy

It wasn‟t before the 20th century that wind energy is harnessed to generate electricity. As electricity was discovered and the motor invented, the first large electric windmill was constructed in Cleveland, Ohio by Charles F. Brush, which had a rotor of 17 meters and turned a direct current generator producing 12 kilowatts of energy.

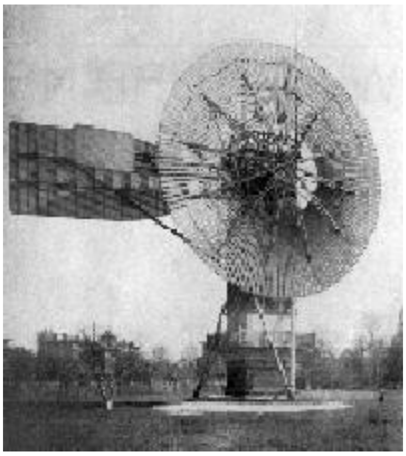

Figure 1-4: First large scale wind generator providing 12 kw of energy (Gardner, P)

Developments of wind energy continued rather slowly, although progress is made in the preceding years increasing the efficiency as well as size of the wind turbines. The US Government took an interest and invested into wind energy a few years after the Arab Oil Crisis of 1973, but despite the amount of money and activity involved, the program eventually died down due to the withdrawal of financial support and political intervention, as well as falling oil prices which rendered wind energy uneconomical.

1.2 OFFSHORE WIND TURBINE (OWT) TECHNOLOGY & DEVELOPMENT

Wind turbines have progressed vastly since the Dutch first used it to grind their mills and have grown in power, from 25kw to 2500kw and more. With the growth of wind turbine size, the tools and engineering expertise used to overcome the challenges of harnessing wind power have also grown and expanded, with computer-aided tools becoming more and more prolific and colleges and universities that have started to offer courses on wind technology.

Modern offshore wind turbines are now required to generate high-quality, network frequency electricity in an independent and automatic manner and do so for 20 years or more continuously with low to no maintenance in some of the harshest environments in our planet. That will be the challenges facing engineers today.

1.2.1 DESIGN STYLES

<u>Vertical Axis Wind Turbine (Darrieus)</u>

Figure 1-5: Darrieus-type VAWTs (Gardner, P)

Initially, wind turbines which rotates on the vertical axis were considered as a design as the expected advantages are omni-directionality and having gears and power generating equipment located at the base of the tower to lower loads. The shape of the turbine is like an onion, also called the „troposkein curve‟. The design failed due to the inherent inefficiencies of the rotor, extra weight in construction as well as serious metal-fatigue problems due to the tension-loaded rotors (Gardner. P., 2002). However, the design is still viable in low-power applications and can be mounted on the rooftops of buildings.

Number of Blades

Figure 1-6: Single and twin bladed rotor design (Gardner, P)

The one bladed design is structurally the most efficient as all the blade area is concentrated on one blade. However, the design needs to spin at a higher speed (relative to multibladed designs) to generate power and this leads to higher blade and tower loads. This high speed often generates a lot of noise which can be undesirable in onshore designs. The use of a counterbalance to give the structure static balance is also inefficient use of weight. Hence commercially, one bladed design has been mostly eliminated.

Two bladed rotor designs is the next design that improves upon the single blade and has a teeter hinge which allows the two blades to move as a single beam, with a +/- 7° of out-of-plane rotation designed to relieve the high loads experienced. However, the apparently unsteady passage of blades through a cycle of rotation has caused it to be almost eliminated from commercial consideration.

Three bladed designs are now the dominant as it offers the best characteristics in terms of lower rotational speeds and more even loads. Most, if not all, modern commercial designs are based on this Dutch three-bladed design.

Pitch vs Stall

According to Gardner in Wind Energy – The Facts, wind turbines utilize stall and pitch regulation in order to limit the rotor power when experiencing high operational wind speeds. Stall regulation is where the speed of the rotor is held constant or approximately constant even under increasing wind speeds. This causes the angle of flow over the blade sections to steepen. In effect, the blades become increasingly stalled and thus limit the power to acceptable levels, without requiring any additional active control.

Aerodynamicists were initially shocked at the idea of using stall as a form of limiting power because in flight aerodynamics, stall is often fatal and can cause planes and helicopters to crash. However, it proved to be effective to control overspeeding and the solution is unique to the wind energy industry.

The limiting of rotor speed is done by connection of the electric generator to the grid; the grid behaves like a giant flywheel, storing energy for the turbine.

Another alternative to stall regulation is pitch regulation. Here, the rotor is turned about its long axis, regulating the power extracted by the rotor. This system requires active rotor control comprising of blade position sensors, power output measurement and a control system which adjusts the rotor angle.

The systems of speed regulation are necessary and crucial because wind gusts happen quickly and suddenly and may cause damage to the turbine due to overspeeding of the turbine blades.

Variable Speed Designs

Initially, the wind industry used fixed speed turbines which were simpler to design and manufacture. However newer designs have started to adopt variable turbine speeds for reasons of improved capture of energy from the wind and because the turbine can be optimally matched to the wind flow for maximum efficiency (Gardner. P., 2002).

Another reason variable speed was introduced is the problem of maintaining smooth electricity generation at high wind speeds (15-20 m/s) on wind turbines that employ pitch regulation. The high speeds introduce very turbulent flows that force the pitch regulation system to constantly change the pitch angle of the blade. Sometimes, the system does not respond quickly enough to the fast-changing flow and the result is excessive power variation. The variation in power put tremendous strains for the electrical system and also to the grid it is connected to.

The costs are higher than fixed speed design but the newer generation of turbines have started to utilize variable speed design widely as it offers more flexibility for the design.

Nacelle Designs

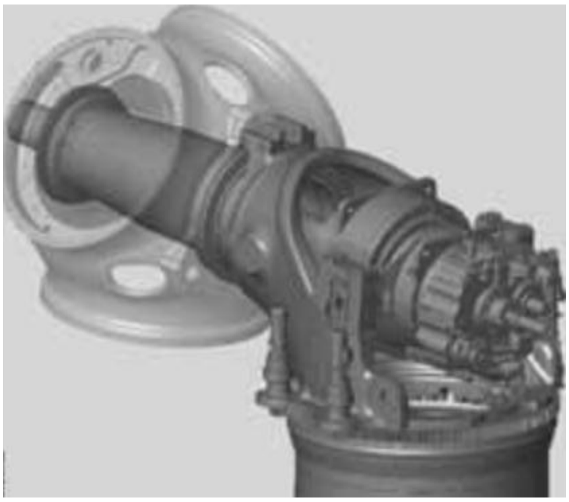

Figure 1-7: Part of the driveshaft connecting the rotor to the drivetrain, housed inside the nacelle. (Gardner, P)

The nacelle of a wind turbine houses the generator, gearbox and drive train which are then connected to the rotors. There are a large variety of nacelle arrangement, from direct drive systems, multi-stage gearing systems and multi-pole generators (as opposed to the more common 2 and 4 pole generators being fitted today). There is still high competition and a clear, efficient design has yet to emerge, if indeed such a thing exists.

Size Trends

Wind turbines have been growing in size/hub diameter. The reason for this is simply because of the economics of scale. Smaller turbines require more maintenance and when compared to large turbines, the cost-per-kilowatt for large turbine is much cheaper. Furthermore, the developments of offshore wind turbines necessitates even larger turbines as it would mean reducing the number of turbines required to be installed offshore and reduce maintenance costs as well. The expensive foundations for offshore turbines also mean it is cheaper to install one very large turbine rather than several smaller ones.

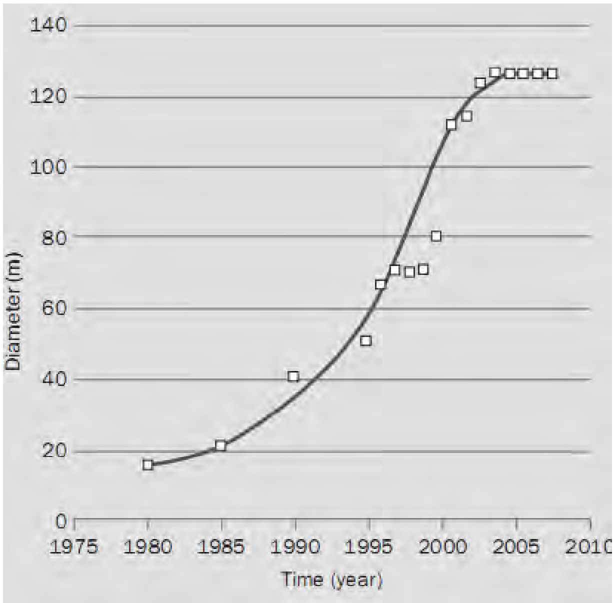

Figure 1-8: Size of wind turbine from 1980 to 2008 (Gardner. P.)

However, there has been no significant growth in terms of turbine size since 2004, as shown in the chart above. Although there are many theoretical works in progress for turbines that are much larger than the current 120m limit, the engineering challenges are still tremendous. With rising oil prices, it is expected that a renewed interest in wind technology will see development of turbines that are rated 10MW and beyond.