Offshore wind turbine installation methods engineering essay

Engineering

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\n[/toc]\n \nA Feasibility Study of Offshore Wind Turbine Installation MethodsInterim Report

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Chapter 1: Introduction

Offshore wind research has boomed since the early 2000s due to many governments and, in particular, the European Commission proposing to increase the proportion of energy supplied from renewable sources. There are many renewable energy sources available ranging from biomass to tidal to wave but the most important renewable source according to (Jacobson, 2009)) is wind energy. In the aforementioned journal, a study was conducted where eleven alternative energy sources were ranked not only on their potential to generate energy, but also on their impact on land, wildlife, human health, global warming and energy security. The study found that wind energy had the potential to reduce carbon emissions and other air pollution by more than 99% when compared to fossil fuels as well as boasting a manageable land footprint. The table below presents all the information in a ranking format. Where a 1 is shown, that source has been determined as the best for that category. Following this, an overall rank was awarded to each energy source with wind coming out on top. renewables ranking. jpgFigure - Environmental Science Journal Rankings (Jacobson, 2009)There have been many advances in onshore wind energy but there are huge capabilities of wind power offshore. This is due to the greater wind speed achieved offshore as well as the limitations of onshore sites. Onshore site developments are restricted due to the effect on the visual environment as well as the noise generated. Therefore the onshore wind market is limited with its site locations as well as the location sizes. With the advancement of offshore wind energy there is an increase in the amount of sites around the world as well as the enhancement of research into the offshore wind capabilities. There is a number of offshore wind farms dotted around the world near coastlines of countries but only recently has the research into deeper water wind been advanced. The advancements of the oil and gas industry into deepwater exploration and extraction have aided the research into offshore wind. There have been many studies into the utilisation of platform types such as spar, tension leg and semi-submersible to host wind turbines in deep water to capitalise on the greater wind energy potential. Figure 2, below shows the concepts of deepwater floating turbines. Floating Wind Turbine Concepts. jpgFigure - Floating Wind Turbine Concepts (NREL)The majority of the research and insight into offshore wind has come from north-western Europe. This is mainly down to the fact that the

European Union and the respective governments of the member states are looking into reducing their carbon footprint as well as harnessing a greater amount of their renewable resources. To look at the United Kingdom for example, the Offshore Evaluation Group Study (May 2009) looked into the UK's offshore renewable resources and found groundbreaking results. The study found that harnessing 29 per cent of the UK's practical wind, wave and tidal resources would match the electricity generated by North Sea oil and gas production. The move would be a huge boost in cutting emissions, saving a cumulative total of 1. 1 billion tonnes of carbon dioxide over the next 40 years. The Kyoto Protocol has had a major impact on the UK and this can be seen in their legally binding target that required they cut greenhouse gas emissions by 12. 5% below their 1990 levels by 2008-2012. Under their own Climate Change Act (2008), the UK is required to cut emissions of green house gas emissions by 80% below 1990 levels by 2050. The report mentioned that harnessing the full potential for offshore renewable energy would generate enough for the UK to power itself six times over at current levels of demand, making it a net energy exporter to continental Europe. practical resources offshore renewables. jpgTable - Total Practical Resource for Offshore Renewables (OVG Study 2009)The UK started its offshore wind development in 2000 with the initiation of the leasing of areas for development. This initial collection of areas was called Round 1. The Round 1 projects consisted of wind farms with 30 or fewer turbines and a net output of roughly no more than 0. 1 GW and were fairly close to the shore. By the end of the developments of the Round 1 areas, the UK has 12 operational projects with an output of 1. 1GW with a further site under development which will provide an additional 0. 06GW. In 2003 the UK began leasing of a further round of areas, Round 2. These areas included areas in proximity to the Greater Wash, the Thames Estuary and Liverpool Bay. Some of these areas were outside the 12 nautical mile territorial waters limit. Compared to the Round 1 developments, the Round 2 wind farms are larger in scale and further offshore. There are 17 Round 2 projects with a total generating capacity of approximately 7. 2 GW. Five of these projects are fully operational at the moment with a capacity of 1. 2 GW and a further four are under construction with a proposed output capacity of roughly 1. 8 GW. A third round of leasing, Round 3, is currently in the development stages with environmental and engineering surveys being undertaken for the proposed sites. The construction of these sites is projected to commence in the middle of this decade. The UK is not the only country developing its offshore locations for wind energy development. In fact, the first offshore wind turbine was installed in Nogersund, Sweden in 1990. Northern Europe started the initial development of the offshore wind farm with Denmark installing the Horns Rev wind power project in 2002. This wind farm had a capacity of 160MW and was a massive step forward from the demonstrative wind projects prior. The development of European offshore wind can be seen in table and the offshore developments of the leading European wind energy nations can be see subsequently in table. ANNUAL INSTALLED OFFSHORE WIND CAPACITY IN EUROPE (MW). jpgFigure - Annual Installed Offshore Wind Capacity In Europe (MW) (EWEA)SUMMARY OF WORK AT OFFSHORE WIND FARMS BETWEEN 1ST JANUARY 2012 AND 30TH JUNE 2012. jpgTable - Summary Of Work At Offshore Wind Farms Between 1st January 2012 And

30th June 2012 (EWEA)Although Europe is leading the development of offshore wind farms, the USA and China are also looking to develop their own projects. In 2010, China connected its first offshore wind farm, the 102 MW Shanghai Donghai Bridge, to the electric grid. A landmark for a country that saw its onshore wind output surge dramatically from 567 MW to 13, 803 MW over the space of six years from 2003. China is one of the largest energy consumers in the world and it is now crucial for them to harness all potential energy for their own economic growth. This initial offshore project is only the first of many as all coastal provinces in China have formulated provincial offshore wind development plans due to National Energy Administration requirements. China. jpgTable - Planning of Offshore Wind Power of Coastal Provinces in China in 2008The USA on the other hand has just been given the go ahead to develop the Cape Wind project. Cape Wind will be America's first offshore wind farm. Located on Horseshoe Shoal in Nantucket Sound, miles from the nearest shore, 130 wind turbineswill be installed providing 420 MW. It is projected that in average winds, Cape Wind will be able to provide three quarters of the Cape and Islands electricity needs. As well as Cape Wind, there are a further two offshore wind projects in the development stage: Bluewater Delaware and Coastal Point Galveston. Although these developments are ongoing, there are still difficulties in establishing offshore wind farms. One of the main difficulties with offshore wind farms is the installation of the platforms, turbines and the subsea infrastructure. There are several platform types used in harnessing the wind energy in unity with the turbines. The platform selection is a crucial aspect of the design stage and it affects the way in which the wind farms are installed. A lot of work has been done on gravity based and monopile platforms for use within the wind industry with many current offshore sites using these methods. However, recently, a lot more research and experimenting has been done with platform methods used in the extraction of oil & gas. These include jacket and tripod foundations as well as branching into the deep water technologies of spar, semi-submersible and tension leg platforms.

Chapter 2: Aims and Objectives

As highlighted in the introduction there is a growing demand for renewable energy and offshore wind has a very high potential for energy output. The aim of this project is to conduct a feasibility study for the installation methods used for offshore wind farms. Because the installation of offshore wind turbines can be expensive and time consuming, a feasibility study would provide a greater insight into which methods are most cost effective for the different substructures. The following is a list of objectives that will be undertaken in order to compile the final study and draw conclusions: Compile relevant information for installation methods of different substructures with and without turbineDetermine which vessels are applicable for the installation methodsResearch costs for crew, vessels and all other installation requirementsDevelop time scales for installation methodsLook into the effects of bad weather on the installation time frame and costCase study regarding a 2nd round UK offshore wind farmResearching mathematical modelling for weather, time and costsCompiling data into a feasibility study

Chapter 3: Literature Review

The extraction of offshore wind energy has faced many challenges over the years and none more so than the economical side of the development of offshore wind farms. When compared to onshore wind farms, the development and installation of offshore wind farms can be extremely costly due to the difficulties faced installing offshore as well as the high costs of plant and vessel rental for offshore fitting and transportation. Regarding the optimisation for offshore wind farms and the techniques used for the most cost-effective development methods, (Butterfield et al., 2007) summarize all methods for the optimisation. The paper essentially provides the groundwork for optimising an offshore wind turbine/platform by considering all three major types of platform (ballast stabilised; mooring line stabilised; and buoyancy stabilised) and analysing the pros and cons of the design stage of each respectively in conjunction with the impact if stability on each design. The design criteria looked at included: buoyancy tank costs and complexity; mooring system costs and complexity; installation simplicity; depth independence; wave sensitivity etc. The factors analysed for the impact of stability include: turbine weight; tower top motion; controls complexity; and maximum heeling angle. The pros and cons are not definite guidelines for design but instead ratings for the ease in which the process can be overcome i. e. a pro suggests that the engineering problem can be easily overcome whereas a con suggests a high degree of difficulty. Pros&Cons. jpgTable - Pros and Cons of Floating Platform Design (Butterfield et al., 2007)The most important information to be taken from the above table is the costs and complexities of the design as well as the installation simplicity which will directly affect the time frame of the project as well as the vessels and equipment required. The paper also outlines the economic goal set for offshore wind turbines: $0. 05/kWh. This paper does not contain many facts and figures for the economic side of the process but it does indicate the costs of design stages, installation, operation and decommissioning. As mentioned in the introduction of this paper, one of the main engineering challenges regarding deepwater wind energy is the economics of the projects. The paper gives a background as to where the economics of the projects take affect: design and manufacture; installation; operation and maintenance; and decommissioning. It also indicates the individual aspects of the aforementioned areas. For instance, platform selection, on one hand, directly affects the amount of material used which can result in higher costs but, on the other hand, the shape may require greater fabrication even with less material which could result in higher costs. Hence, this information insists that the platform choice should be economically efficient but not compromise the optimum design. It also stresses that the offshore oil & gas platform design has advanced rapidly over the last few decades but there has been a limited demand to utilise offshore wind, especially in deepwater. It mentions that a lot of the time the oil & gas platforms are produced singularly with high fabrication costs whereas offshore wind turbines would be produced and installed in batches around 100 units. The increased amount of units would in turn lower the cost per unit as only one design is required. The other major player in the costs of the project is the installation. It states that ' any platform that is stable during float-out with a fully assembled turbine will avoid the high cost of special purpose ships to carry and place the turbines on site.’ It proceeds to stress that these self-stable platforms would only require tug boats or buoy tenders to transport them to the site. It also highlights that this would reduce life-cycle costs as it would enable long term maintenance to be done onshore and reduce the effort required when decommissioning. Again, like in the other papers, this research highlights the importance of considering the weather conditions when looking at installation time periods and, ultimately, costs. It points out that the bad weather will result in delays which, in turn, cost the project stand-by fees and wages for crew members that are idle. Hence, it suggests that the platform, fitted with turbine, should ultimately be able to be towed out in more demanding sea states to, again, reduce long term maintenance and installation costs. As mentioned before the offshore wind farm units would be mass produced in numbers of roughly one hundred or more per site. As well as reducing the design and fabrication costs, this method would also affect the installation costs by providing higher quality as well as safer working conditions while at the same time limiting the affect on the installation time frame by poor weather conditions. Cost Breakdown. jpgFigure - Example of Planned Offshore and Onshore Installation Costs by Component (CA-OWEE 2001)From this paper it can be concluded that weather and field size can play a large part in the installation time for offshore wind farms. It highlights the increased effort in the installation process that the cost of the turbine plays a 50% less economic role in the installation process compared to onshore wind farms, see Fig. 1. By suggesting what the authors believe to be the optimum installation model for a floating turbine it will provide this study with a challenge to either prove or disprove this theory with an in depth analysis of all possible installation methods. The paper briefly touches on the vessels required to install the platforms and turbines but doesn't go into great detail.(Thomsen, 2011) goes into greater detail to describe the vessels required for the installations as well as discussing the common methods used for installation. This book covers all of the topics related to offshore wind farms' design, planning, and installation. The two chapters of this book that particularly relevant to the proposed thesis were chapters eleven and twelve; commonly used installation methods and vessels & transport to offshore installations. Chapter eleven discusses all of the existing fixed platforms (gravity based, monopile, jacket, and tripod) and their respective means of installation. It provides insight into the design period and fabrication of each foundation. The chapter elaborates on the timescale for the manufacture of each foundation and the construction facility requirements; either for the fabrication itself or the storage afterward. The author then goes on to describe the installation methods for each of the individual substructures including the types of vessel required and their capabilities. For example, when discussing the installation process of a gravity based platform, the following three installation vessels were proposed: A large floating crane. The capacity if the crane should be more than 2500 tons in order to actually lift and place the foundation on the seabed. A very large barge that can transport and possibly store a number of the foundations onboard. A tugboat or group of tugs that can tow either the barge or both barge and crane into position in order to set the foundation in the right location. New-Turbine-Installation-Vessel-to-Arrive-at-Sheringham-Shoal-Offshore-Wind-Farm.

jpgFigure - Jack Up Barge During Installation (World Maritime News)As far as the economy of the installation is concerned, the author states that ‘ competition between different contractors gives better transparency in the price calculation, which give the wind farm owner a fair chance of saving money.’The author stresses that although several vessels may have the lifting capacity to lift the structure into position the vessel must be analysed to see whether the footprint of the substructure fits on the vessel. The book also gives an example of vessel selection given a certain location. It uses an average speed if vessels as well as the required trips to be made to supply all of the individual parts to the site to create a table of what vessels are required and for how long. These are then used in conjunction with the average cost per day of hiring the vessels or machinery to provide an estimate for the cost of the process. The subsequent chapter in the book discusses the options available by way of installation vessels. It discusses the use of self-propelled jack-up vessels, tug-assisted and self-positioning jack-up barges and floating equipment. It assesses the equipment, taking into consideration the basic information of the vessels and equipment: length, area, loading capacity etc. It also looks into the operations and bookings of the vessels. This considers the chartering costs, the minimum charter period, and, also, the mobilisation and demobilisation costs. Thomsen summarised the need to identify the method that will be used for installation as well as the requirements that come with it. He stressed that although some vessels are capable of installing platforms of similar mass they might not be suited to the size and footprint of the structures and so vessel choice is paramount in the installation process. However, when selecting a vessel for the installation job one must consider the costs that occur when utilising the vessel. Where Thomsen's book didn't give great insight was the modern day costs of designing and installation costs there were others that highlighted the economics of the installations. For example, (Gaudiosi, 1996) pointed out the concerns in monetary value for offshore wind farms. The paper is a generalisation of the status of the offshore wind energy industry and a look into the possible future of it. Although it talks a lot about the potential of the offshore wind industry and the environmental, social and safety issues of the projects it does briefly mention the economy of the installation of the offshore wind farms. It suggests that offshore wind farm installations with sea bed foundations have roughly one hundred percent greater costs when compared to onshore wind farms. The paper also states that modern installations of offshore wind farms should have an investment cost to MW output ratio of less than two. It also suggests that feasibility studies should be undertaken to for single and multiple turbine platforms as well as floating platforms. By suggesting that further feasibility studies should be undertaken this paper provides validation for this thesis but it does not provide the economic modelling that would be required to carry out these studies. Two papers that provide economic modelling techniques are (Kaiser & Snyder, 2012) and (Herman, 2002). In the earlier paper by Herman an analysis is run on the costs of transportation and installation methods for known platform and turbine models. This is done using the OWECOP II model that was created by the Energy Research Centre of the Netherlands. This model consists of two individual programs. The two programs are: a Geographic Information System (GIS) and an Excel spreadsheet program. The GIS is a database that contains maps of investigated waters and their respective wind speeds, water depth, significant wave height and distances to both harbours and grid connections. The Excel spreadsheet takes into account the costs of the foundations of an offshore wind farm. The spreadsheet contains the costs for: the turbine; the support structure; electrical infrastructure; transport; installation; operation and maintenance etc. The costs of the transport and installation have been based on known offshore techniques and they have been structured according to the potential wind turbine assemblies. The paper also takes into account the miscellaneous costs such as: scour protection; soil research; cable installations; and decommissioning. The paper looks at eight different configurations for the installation of the turbine and weighs up the pros and cons of each configuration regarding cost and risk. Despite elaborating on all of the possible substructure platforms that are available, the paper only focuses its' analysis on three foundation types. The three foundation types that are analysed are: gravity based; monopod; and tripod. The paper also looks at the methods for transport and installation. Separate transportation & installation and combined transport & installation. The separate method uses either a cargo barge and towing tug or a crane barge with sufficient cargo area. The combined method focuses itself on two methods also: a jack-up vessel or a construction vessel. The costs of these transportation methods are evaluated with the mobilisation and operational costs analysed. The operational costs are given as day rates and hence the subsequent part of the paper reviews estimated time scales for mobilisation, loading and unloading, and transporting to sites. The paper then analyses the installation methods used for the three substructures that were previously mentioned. It estimates the time of the installation for each configuration as well as providing a step by step methodology for the installation process including the required equipment. The paper also reviews the weather conditions in order to determine the savings or loss of simultaneous transport or inability to work. Formulae for such conditions have been created to estimate the savings from simultaneous transport and/or the loss due to unworkable weather conditions. The formulae have been created using probabilistic methods for calculating the time required in bad weather. Using the OWECOP II method the estimated time and cost values are calculated for monopod and tripod structures. It also suggests that the size and weight of the wind turbines should be included as to avoid overestimating the transport and installation costs and that installation and transport vessels should be updated regularly to account for new models to investigate if the new vessels would be competitive in the market. Herman's paper provides an in depth insight into all the costs of the installation process for the three foundations as well as a mathematical and probabilistic model for calculating total costs. By suggesting that other parameters should be included in later models it shows that this is not a finalised piece and that development can and should be taken to the next level. The Kaiser & Snyder paper focuses on the installation of wind farms in North American water but only focuses on the monopile substructure. It develops a framework in order to estimate the installation costs expected in the future offshore wind developments of the USA. The research into cost analysis within this paper is done using the expected market conditions of the time frame 2012-2017 which is done to estimate the installation costs of certain stages e. g. travel, loading, and installation. The empirical formulae developed within the paper are based upon data regarding northern European wind projects. As mentioned, the paper only deals with the installation of monopile substructure wind turbines in shallow water depths but the authors stress that this is simply a framework and that alternative ‘ parameterisations’ may be used for application outwith the technical boundaries that have been imposed. The basis of the paper is to provide estimates for vessel and equipment requirements so as to provide comparisons between wind farm installation methods at the design and development stages. The paper features several tables that include time estimations for the installation of several transport methods and turbine capacities whilst considering the effect of bad weather conditions. The paper doesn’t include the multiple installation methods of the Herman paper nor does it further the use of different substructures but it does include three applied analysis regarding offshore wind farms in the USA that are in their late development stages: Cape Wind; Bluewater Delaware and Coastal Point Galveston. Both of these papers are very detailed into the modelling of costs but the lack of substructures analysed yet again provides validation for this thesis. All of the papers read and reviewed were very insightful and detailed. They provide an excellent background understanding of what is required by offshore wind installation but the lack of focus on deeper water substructures implies that this is a modern concept that is still to be fully analysed. This thesis will look to analyse the installation methods for all offshore wind substructures and aim to provide the detail that isn’t available through the aforementioned literature.

Chapter 4: Future Plans

gantt. jpgTable - Future Plans