CHALMERS
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Challenges of achieving a high accessibility in remote offshore wind farms

How will changing operational requirements affect access strategy during the operation and maintenance phase?

Master's Thesis in the Nordic Master's Programme in Maritime Management

CHRISTOPHER ANDERBERG

Department of Shipping and Marine Technology
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2015
Master Thesis NM-15/46

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ABSTRACT

The wind offshore industry has experienced a vast development since the start in the early 1990's. At the end of 2013 there were 117.3 GW of installed wind energy capacity in the EU: 110.7 GW onshore and 6.6 GW offshore. A natural consequence of development offshore is a need for suitable vessels to undertake the assignments that arise from site development, site construction and further on to site operations and maintenance. During the operation & maintenance phase, which involves various support activities to carry out planned or unplanned maintenance, special designated Crew Transfer Vessels (CTV) conduct the majority of these. The tendency for wind offshore is to develop more and larger farms further offshore. There exists a need from many perspectives to develop and optimizing the access systems and the procedures around it in order to meet new operational demands for future wind farms. This thesis main purpose is to investigate how changing operational requirement in remote offshore wind farms will affect the safe and efficient transfer of personnel to wind turbines. To answer this, a qualitative research approach was selected where a mixed methodology was carried out involving on-bard observation on a real wind farm crew transfer vessel and through semi-structured interviews.

Two main conclusions were drawn in the study. Firstly, the ambition for a high availability in remote offshore wind farms is crucial for the development and also to defend that push to be attractive in the future. The level of availability is dependent of an acceptable level of accessibility. Far offshore wind farms will require that the operational margins for crew transfer need to be increased in maintaining that. The limitations of the CTV's can to some extent cover that and still remain safe and efficient, but an increased transfer time will limit that option.

Secondly the SOV (Service Offshore Vessel) or other accommodation concept will cover the duties in working in rougher sea conditions however its efficiency in technician distribution needs to be increased if this should remain a cost effective solution.

Keywords: Accessibility, access systems, crew transfer vessel, offshore wind, operation and maintenance, offshore wind turbine, service offshore vessel

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PREFERENCE

This thesis is a part of the requirements for the master's degree in Maritime Management at Chalmers University of Technology, Göteborg, and has been carried out at the Division of Maritime Human Factors and Navigation, Department of Shipping and Marine Technology, Chalmers University of Technology between January 2013 and June of 2015.

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Christopher Anderberg

LIST OF ABBREVATIONS

DP	Dynamic positioning
HF	Human Factors
HTA	Hierarchical task analysis
STCW	Standards of Training, Certification and Watch keeping
PTV	Personnel Transfer Vessel
WFSV	Wind Farm Support Vessel
CTV	Crew Transfer Vessel
SOV	Service Operation Vessel
Hs	Significant wave height; defined traditionally as the mean wave height (trough to crest) of the highest third of the waves
O&M	Operation and Maintenance
IMR	Inspection, Maintenance and Repair
OWT	Offshore Wind Turbine
UK Round 1	Wind farms in from coastline out to distance of 12 nautical miles
UK Round 3	Includes nine zones across the UK with a total capacity of 25GW, including the Dogger Bank
HTA	Hierarchical Task Analysis
NM	Nautical Miles
RIB	Rigid Inflatable Boats
IMCA	International Marine Contractors Association

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1 INTRODUCTION

This chapter contains an introduction to the wind offshore area and the thesis main background; it also covers the thesis main objective, academic relevance, scope and limitations and finally the structure of the study.

1.1 History of Wind Power Offshore

The use of wind to produce electricity began in Scotland in 1891, where James Blyth demonstrated by the use of a vertical-axis wind turbine the ability to transform wind power into electricity in a limited scale. It was not until 1970s that a stronger development took place of onshore wind turbines in Europe and in the United States (MacAskill & Mitchell, 2013). Onshore wind has gone through a great development, however the industry has experienced complications which has limited its growth. Often has this been driven by visual intrusion and noise complaints. The interests have then turned to offshore where these complications were not of any public concern and even the energy potentials have been considered as larger. The development started in Sweden in 1991 where the first wind power unit was installed outside Nogersund and the first offshore wind farm was installed outside Vindeby, Denmark with 11 turbines producing 450 kW each. (MacAskill & Mitchell, 2013). The first "utility-scale" project was developed in Danish waters in 2001, where 20 turbines with a total capacity of 40 MW became operational. Since 2001, where 50,5MW of installed offshore capacity represented 1 % of the total European wind capacity, the development of total capacity have increased annually. At the end of 2013 there were 117.3 GW of installed wind energy capacity in the EU: 110.7 GW onshore and 6.6 GW offshore (EWEA, 2014). The main development has been seen in the European area connected to the North Sea and the Baltic Sea however other areas are under development in countries like United States, Canada, South Korea, Taiwan and China (MacAskill & Mitchell, 2013)

1.2 Thesis Background

A natural consequence of development offshore is a need for suitable vessels to undertake the assignments that arise from site development, site construction and further on to site operations and maintenance. Depending on the requirements in the operations these needs vary from basic generic vessels to purpose built vessels, designed for specific installations tasks. Given the expected forecasted development in the European offshore wind energy market within the next ten to twenty years, the demands on the involved vessels will increase (EWEA, 2011,)

This thesis will focus on the sequence involving O&M duties; these activities often involve the transport of technicians and their equipment to and from the site for IMR (Inspection, maintenance and Repair) duties.

Traditionally 12 passenger workboats have been used for these operations. Since the ambition of wind farm development is to go further out at sea, longer travel distances or response time might require needs for different vessel concepts and other methods than traditional work boat solution. For example helicopters are becoming more important to use for accessing the turbines, other concepts involves "Hotel-ships" and different kinds of accommodation units for larger and more remote wind farms.

MacAskill and Mitchell (2013) also highlights the challenges in remote areas as a key driver to find solutions that could encounter rougher weather conditions, longer transfer time and at the same time are cost effective. A necessity for an offshore wind farm is to maintain low down times during the operational phase in order to have it cost effective. Getting the technicians to the farms for their duties, the access system and the procedures around are often seen as the key in securing these in a safe and effective way.

The majority of offshore wind farms today are often located less than 25km offshore in relatively calm operational conditions and normally consist of about a 100 wind turbines. Normal duties concerning maintenance and inspection is possible through the use of CTV (Crew Transfer vessels) or by other workboats operating from a nearby port. These operations consists of 90 % of the time when the wave heights are up to about 1,5 m significant (Hs) limit and with an accessibility for around 300 days a year (Carbon Thrust, 2013).

New planned wind farm projects offshore for the UK round 3 sites for example have an average distance to shore of 65 km(35 NM), these farms will encounter much rougher conditions and may consist of 600 turbines. With the status and operational capability of today's access systems and procedure, this will only allow accessibility for about 210 days a year in 1,5m Hs and that is far too low to keep a farm operational. Increasing the wave height limit to 3.0m Hs will allow an accessibility of 310 days a year (Costa, 2013).
There exists a need from many perspectives to develop and optimize the access systems and the procedures around it in order to meet new operational demands for future wind farms. The number of wind farm support vessels has grown and in this emerging fleet the concept of a safe transfer of personnel to the wind turbine unit is the most important objective. It must be done in a safe and efficient manner through certain access points or boat landings. General practise within the industry has been to "butt" the CTV tightly against friction bars on the wind turbine and hold it there with forward propulsion (Marsh, 2013).

1.2.1 The European Strategy for the Offshore Wind Sector

The target of the European Wind Energy Association (EWEA) is to reach 230 GW of installed wind power in Europe at the end of 2020, 40 GW of these should come from Wind farms offshore (Besnard et al, 2013). This aligns with the European strategy for renewable energy and in the spring of 2007 the Council of Ministers agreed on '20:20:20' goals, the intention is to cut greenhouse gases emissions by 20 % from the 1990 levels, improve energy efficiency by 20 %, and secure 20 % of Europe's energy demand from renewable sources – all by 2020(Carbon Thrust, 2013). The European commission predicts with reference to year 2013, a slightly lower demand compared to previous predictions from 2009. The forecast predicts 204 GW and offshore winds stands for almost 48 GW. The reason for reduced prognosis is due to the economic downturn in Europe. This has affected investment plans, new orders, investment decisions already taken, and existing installations in markets across Europe both onshore and offshore (EWEA, 2014)

1.2.2 Offshore wind industry – trends and potentials

The expected tendency for offshore wind farm development is to go deeper, bigger and further out at sea. The new Dogger Bank project "Dogger Bank Creyke Beck" that was announced in early 2015, has a total generating capacity of 2.4 GW through two different wind farms containing around 400 turbines. This demonstrates the new potentials for far offshore wind farms. The offshore wind farms will be located in the Dogger Bank Zone which is located around 71 NM off the east coast of England (MarEx, 2015).
This puts huge challenges in all phases related to construction and operations of wind farms offshore. The majority of wind farms available today are concentrated to the 20x20 zone (20

km from shore and in 20 meters depth). Most of the future offshore wind farms will become bigger in terms of capacity and going into deeper waters, in some cases go further out at sea as seen in figure one (EWEA, 2011).

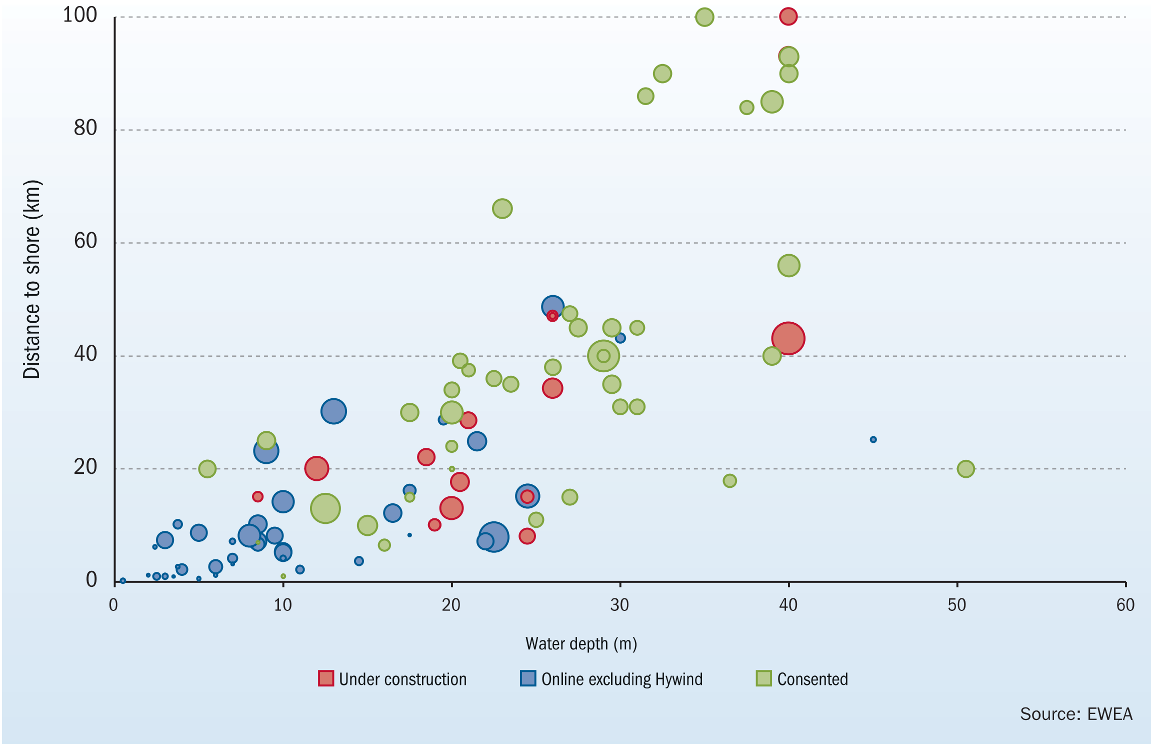


Figure 1 – Present status of online, consented and under construction offshore wind farms (EWEA, 2011)

The analysis based upon EWEA's information and present trends reveals that the major projects are still beneath 60 meters of depth; however they vary in relation to distance from shore. Still the majority is found in the 60x60 area, but there are fields that extend in distance in relation to the depth 60m. The ones that exceed 60 meters of depth, mainly related to deep offshore wind farms will most likely involve new concepts of wind turbines. These floating units are under development however in reaching a field deployment require further modifications and testing to overcome the operational constraints of the sea (EWEA, 2011).

1.3 Academic Relevance

The subject area is appropriate of an academic relevance as it addresses an area where research needs to be involved more in the process and development. It's also an emerging industry were new design concepts and various technology solutions constantly is entering the market and changing the operational environment.
The safety aspects in accessing a wind farm turbine are of outmost importance and need to be examined further in order to secure strategies in the development of access systems and evaluate procedures in relation to remote offshore wind farms.

1.4 Purpose

The main purpose is to investigate how changing operational requirements affect operational limits for Crew Transfer Vessels in order to secure safe and efficient maintenance and support operations in remote offshore wind farms.

1.5 Research questions

The research questions have been formulated based upon two main areas, followed by two sub-questions:

1. What are the present operational limits in practise that affect the operating window for maintenance and support tasks for Crew Transfer Vessels?
   a. What type of procedures and access systems exists today in order to meet these limits?
2. How will remote offshore wind farms affect the operational limitations for the operation and maintenance phase?
   a. How can existing procedures and access system be developed in order to meet new operational requirements?

1.6 Limitations

This thesis does not focus on technical aspects, so various design of vessels and access system options have been left out, only short description of different concepts are published. The focus on the thesis is not to add any comments or judgements on different matters on design in order to have a more objective view on the subjects. Further on, the thesis focus only on the O&M phase.

1.7 Structure

This structure is based on traditionally academic approach and layout. It starts with an introduction to the topic and followed by theory description. After that comes the method description, followed by findings chapters and a discussion chapter, which make out the body of the whole dissertation. In the end there is a conclusion chapter.

2 THEORETICAL OVERVIEW

2.1 Offshore wind farms

The primary components of an offshore wind farm include several turbines placed in a special designated area and these are connected by a series of cables to an offshore transformer or substation station. This one is further on connected to an onshore transformer station before the electricity finally enters the grid.

The wind turbines are often placed latterly and divided to minimize the wake effects and turbulence. Placing the turbines closer to each other also reduces the amount of cables put down in the water. The position of each turbine must be planned in detail in order to maximize the power generation for an effective cost per unit optimizing (Malhotra, 2011).

In Europe the wind farms are growing in terms of total project capacity and this development has affected the size of individual turbines. In 2011 the average size of an offshore wind project was 199 MV and already by 2012 this number has grown with 36 % to 271 MW. Looking upon the future planned projects, the average size could be over 500 MW (EWEA, 2013). The new Dogger Bank project "Dogger Bank Creyke Beck" that was announced in early 2015 has a total generating capacity of 2.4 GW through two different wind farms containing around 400 turbines, demonstrates the potential of far offshore wind farms (MarEx, 2015)

2.1.1 Wind farm Turbines

The wind turbines offshore have gone through several design considerations; these have to meet more loads and environmental conditions than those onshore. Sea waves, currents, ice impacts from CTV's and even wild life have to be considered while designing the turbines and could have a great effect on the turbine foundations.
A wind turbine consists of many complex components some located above the waterline and some below and the most common used today are monopiles.
In the development of new fields further offshore and as technology for wind turbines improves, the industry needs stronger and bigger wind turbines to optimize the cost benefits. Turbines that have a 150 m of rotor diameter with the capacity of 7, 5 – 10 MW could be a reality in the future which creates new operational challenges as some of these might be floating units (Malhotra, 2011).

2.1.2 Different phases for offshore wind projects

An offshore wind project go through different phases during its lifetime and selection of the site requires a great amount of consideration. The obvious consideration is the area where the greatest amount of wind is located however some other important aspects are:

- Distance from shore
- Proximity to electrical grids, companies and the undersea cables
- Visibility
- Disturbance of any routes for airplanes and ships
- Bird migration flight paths

(Nicole, 2013)

When these factors have been considered the design, construction and installation of the wind farm can begin. When the installation process have been completed and the wind farm has been connected to the grid ashore, the commissioning can be complete as a final verification of functionality and operability. After the commissioning of the wind farm, it's ready to produce electricity during the operation and maintenance (O&M) phase of the turbines and the farm (Nicole, 2013).

2.1.2.1 Operation and Maintenance (O&M) of an offshore wind farm

This phase relates to two main activities as implied by the name:
Operation – this refers to mainly management and "operations" of the farm or project and includes such as remote monitoring, environmental monitoring, electricity sales, marketing and other office tasks. Operations involve only a small proportion of O&M costs.
Maintenance – these activities stand for the largest part of total O&M effort and cost. This part refers to inspection, maintenance and repair of the physical plant and is divided into two main areas:

- **Preventive maintenance** – involves scheduled or proactive repair to, or replacement of known wear components based upon routine inspections or by information from different condition monitoring systems. Activities such as routine surveys and inspections are included.
- **Corrective maintenance** – involves reactive or unscheduled repairs or replacement of failed or damage components. This may also affect serial-defects or problems that affect several wind turbines at one site.

(GL Garrad Hassan, 2013)

2.1.3 Accessibility and availability

The issue of accessibility is determined by the percentage of how much that turbine can be accessed, this is a major factor that will affect the operation of an offshore wind farm (Salzman et al, 2009). Access difficulties can be highlighted in the effect of device availability; availability is defined by the amount of time the turbine is operational to create electricity (Faulstich et el, 2009). Availability is therefore dependent on a number of factors such as failure rates, downtimes for recovery after failure, non-accessibility, lack of spare parts and logistical problems, which will have affection on availability.

The accessibility in the offshore wind farms is especially critical due to loss of production from an OWT (Offshore Wind Turbine) which is often the greatest cost penalty for the wind farm operator (EWEA, 2009).
According to Van Bussel (2002) *"for a 150 unit wind farm consisting of 2 MW wind turbines at least 600 visits have to be paid each year to keep it in full operation"*.
Van Bussel also highlights local conditions as predominate factors that affect accessibility but this is also dependent upon the way which the turbine is accessed. For example, the large offshore wind farm in the North Sea at Horns Rev, the availability is around 90 % with accessibility by vessel on 65 % (Van Bussel, 2002). With reference to year 2013 the average availability rate was between 90-95% for a typical offshore wind farm (GL Garrad Hassan, 2013). This can be compared with an onshore wind farm with availability on 95-99 % (Dai, 2014).

In order to ensure a high availability for offshore wind farms, fast on repairs or device recovery must be done, that require that the level of accessibility needs to be quantified in order to ensure good economics (O'Connor, 2012). A majority of all the maintenance on an offshore wind turbine requires transfer of personnel and of parts hoisted up by the turbine's internal crane, according to Rademaker & Braam (2002) this transportation and access can be done in (Hs) up to 2.0 meters. However, according to Salzman (2007), even if the vessels are being built stating workability up to Hs 2.0 m, the operators claim a more adjusted level between 1,5-2,0 m Hs.
In the study from Van Bussel & Bierbooms (2003) looking upon different methods of transportation during the O&M phase for a wind farm located 45 km (24NM) off the Dutch coast. The study established the following table 1, were different level of accessibility was estimated from different wave height limits.

Table 1 –Illustration of level off accessibility (compiled from Van Bussel & Bierbooms, 2003)

Wave height limit Hs(m)	Accessibility (%)
0,75	34
1,5	71
2	84
3	95

The study reveals accessibility on 71% on wave heights around 1.5 m Hs and 84 % accessibility on Hs 2.0 meters.
These numbers were almost confirmed by Salzman (2007) who did a similar study looking upon yearly distributions for two different fictitious wind farms; one located 37km (20NM) offshore and one located 100km (54NM). Table 2 demonstrates the values of accessibility for the two farms.

Table 2 – Different level of accessibility for two different farms (compiled from Salzman, 2007)

Distance to shore	Year-around accessibility %				
	Hs= 1,0m	Hs=1,5m	Hs 2,0m	Hs=2,5m	Hs=3,0m
37 km	45	68	83	91	95
100 km	36	60	76	87	93

The study indicates that if the access system (vessel and transfer method) can work up to 2.5 m Hs it can be used for around 90 % of the year for both farms.

2.1.3.1 Accessibility and economy

In order for the industry to be competitive and cost efficient in the future the level of availability needs to remain high. Therefore it's important to identify a relevant level of accessibility to an offshore wind farm, the costs and incurred revenue losses for downtimes due to none-accessibility are strong incitements to develop access technology (Dahlén & Jakobsson, 2009). In order to found ambitious large-scale offshore wind projects it's important to reduce the risks for possible investors. The wind turbine availability is the main factor influencing as it determines the obtainable income factor directly (Scheu et al, 2012).

Demonstrated in figure two illustrates indicative trends of cost of O&M in relation to availability.

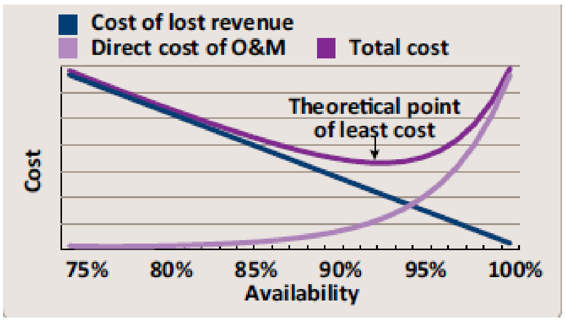


Figure 2 – Costs connected to different levels of availability (GL Garrad Hassan, 2013)

Even if the cost of lost income declines zero as the turbines approach 100 % availability, the total cost in achieving that will increase dramatically.

As the wind turbines is planned to become larger in the future, the risk of increased losses per unit time is an important aspect that affects tractability for further investment in the offshore wind sector. When the wind farms intend to move further out as sea, projects intended to become more complex, therefore, an optimal availability and cost effectiveness will require better accessibility (Dahlén & Jakobsson, 2009).

It’s important in O&M strategies to have an overview over the costs associated with the operations of the wind farm, it’s also important to work with good models in order to plan for maintenance and inspections in order to reduce costs (Rademakers *et al*, 2008). Operation and maintenance costs are expected to stand for around 15 – 30 % of the cost of energy generated by offshore wind, maintenance and support strategies are vital to control these costs (Fischer et al, 2013).
As a significant contributor to the total cost of energy, finding or exploring different concepts to reduce the cost of O&M services and optimizing asset performance have important role in the future (GL Garrad Hassan, 2013).

2.2 O&M strategies for offshore wind farms

The main activity for offshore logistics is to cover the duties related to operation and maintenance (O&M), mostly focusing on transporting technicians and their equipment out to the different wind farms for their different duties. Each offshore wind project has different characteristics, which determine the optimal strategy for operating and maintaining the plant, the main factors are:

- Distance from onshore facilities
- Average sea state
- Number, size and reliability of turbines
- Offshore substation design

(GL Garrad Hassan, 2013)

The most influential factor affecting, is the distance from onshore facilities to the offshore wind farm, this factor has the largest impact on the cost associated with O&M for wind offshore projects. For this reason, the distance from shore is also the primary consideration when determining the most cost-effective approach to O&M. There are three factors to consider regarding vessel concepts for O&M duties:

- The weather conditions, more focusing on wave heights, wind speed and currents, affecting the operability of the vessel, personnel safety and accessibility of offshore structures.
- The distance between the port and the working area, this together with a particular vessel's transit speed decides the required journey time and therefore the actual working time on site.
- The water depth in the working area, however this has more affection on jack-up rigs, which have a limitation on working depth.

(Bard & Thalemann, 2011)

A study by the ship design consultancy BMT Nigel Gee assumes 15 person-days of planned maintenance per year for a standard 5 MW wind turbine (Bonafoux, 2011) another suggestion is 40h of planned maintenance per year for a wind turbine (Zander, 2009

The transport consultancy UNICONSULT suggests the following data (Bard & Thalemann, 2011):

- A team of 5 technicians will probably be needed for conducting a service job on one wind turbine at the time, two will probably be seasick during the journey out, and by that unfit to enter the wind turbine. The 3 technicians that remain can conduct the work.
- The Manufactures calculate with 6-7 technical malfunctions per turbine and year, these can be handled in one day of work or less.
- 100 % of the wind turbines undergo an inspection once a year. During the inspections much of the components are verified carefully and malfunctioning items are replaced. This will take 2-3 days per turbine.
- 100% of the foundations and 50 % of the cabling undergo planned inspection of 1 day once a year.

A consulting firm for the renewable energies PROJECT53°, stated in May 2010, that the upcoming offshore wind parks in the North Sea and the Baltic Sea are planned to contain around 80 or more wind turbines and possible distances will be more than 60 NM, this will have affection on vessel strategies and capacity.
The options in reducing this transportation will have impact on site availability, therefore the choice of vessel fleet composition and the investment in potential offshore platforms will have great impact on O&M costs (Halvorsen-Weare *et al*, 2013).

In the study by Besnard *et al* (2013) *A model for the Optimization of the Maintenance Support Organization for Offshore Wind Farms,* modelled different support organization and cost-based optimization in relation to location of maintenance accommodation, the numbers of technicians, the choice of transfer vessels and the choice for helicopters. The model was based upon a generic wind farm of 100 turbines of 5 MW each and located 60km (32NM) offshore. The most cost efficient solution was to use an offshore accommodation on service 24h / 7 days a week, and a crew transfer vessel with a motion compensated transfers system (Fisher *et al*, 2013).
Utne (2010) identifies some important aspects in her study *Maintenance Strategies for deep-sea offshore wind turbines,* that the needs for maintenance and maintainability are used as a base for analysing and modelling optimization of planning and execution of maintenance actions. These are verified with operational experience and through tests, a maintenance strategy can be established for a certain deep offshore wind farm, further cost reduction can be achieved and availability maintained.

Even with an almost perfect wind turbine, considering design, components simplification and reliability of components, maintenance will always be necessary (Utne, 2010). Developing new concepts of deep-sea offshore wind farms/turbines and at the same time trying to reduce operations and maintenance costs is a complex process involving many different people with different knowledge. Due to the fact that design of the different parts in a wind turbine are carried out in different work groups compared to those working on maintenance and support activities creates a transfer gap. This separation imposes challenges with the need to share information and exchange of knowledge. It's therefore hard to assess how different design solution affects maintenances and support tasks (Utne, 2010).

In another study carried out by Scheu *et al* (2012) *Strategies for large offshore wind farms;* the focus was to evaluate how different variations in maintenance fleets can be optimized dependent on different weather forecasts and with the respect of site availability, cost savings and deployment of equipment.
For the study a hypothetical wind farm where selected with a capacity of 2.5 GW close to the UK east coast consisting of 500 turbines, each with a capacity of 5MW.
With regards to fleet variation four different combination of fleet sizes were considered, the alternative with the largest fleet (3 vessels with 3 cranes) had the highest availability achieved with slightly above 90 % (Scheu *et al*, 2012).
The study focused on wave height boundaries from 1 – 2,6 m. At the limit of 1,4 and above an increased numbers of ships increased the availability and the alternative, with one ship and one crane ship only, secured a availability of slightly above 80 %.

In the weather forecast scenario the number of deployments were observed in relation to "look ahead time (48h)" from weather forecast (predicted weather). In this scenario the same type of vessels were used. The Crane vessels have a stronger amount of number of deployments compared to the ordinary ship, the reasons were shorter transit and repair times and the ability to stay longer at the field compared to the ship that has to return to port for new loadings (Scheu *et al*, 2012

A 5 MW turbine was used as reference with all different fleet combinations and the highest boundaries have been evaluated for the diagram, a strong linear correlation exists between availability and production losses. For example a change of wave height boundary from 1,0 to 1,8m for both access methods in a "one ship one crane ship" configuration, would decrease losses with 30 %. The study also concludes that a cost savings can be achieved with better and more advanced access systems.

2.3 Different Access systems

In the literature access systems are sometimes used as a phrase for transportation vehicles (i.e. vessels and helicopters). The access systems used today differ in design, concepts and with procedures ranging from boat-ladder landings (CTV's), lowering from helicopters, temporary gangways lowered from larger vessels. This also involves complex platforms developed by other industries (Dai, 2014).

Environmental conditions like wind, sea state, current etc. have huge impacts on the operations of different access systems; vessels are limited mainly by wave heights and currents and helicopters by high wind forces and visibility. The task of finding a suitable access system is complicated with regards to technical implication and the cost for purchasing (Dai, 2014). Seen below in table 3 are different characteristics of different access methods presented with their operating limits, advantages and disadvantages. Different types have different capabilities and all has to be evaluated depending maintenance strategies, travel distances and field characteristics.

Table 3 – Different access systems (compiled from Knudsen C et al, 2011)

Type	Significant wave heights in metres	Average wind speed in m/s (1hr at 10 m height)	Example of application	Advantages	Disadvantages
Direct boat landing	0,5 - 1,5 (rubber boats) 2,5 (SWATH)	10	Nysted (rubber boats) Bard 1 (SWATH)	Simple	Sensitive to marine growth and icing
Boat landing with motion compensation	2 - 2,5 (OAS) 2 - 3 (Ampelmann)	11,5 (OAS) 14 (Ampelmann)	Tested	Not sensitive to marine growth	Installation of additional equipment on the vessel required
Crane hoist	2,5	?	None	Not sensitive to marine growth	Remote control of crane, Maintenance offshore required
Helicopter	None	15 - 20	Hors Rev, Alpha Ventus	Not sensitive to waves, fast transport	Expensive

2.3.1 Helicopters

This is an additional service that can be used together or separate from the workboat solution, helicopters have short transit time and can operate without regards to sea conditions and by that better accessibility. However the cost associated with helicopters is much higher and another disadvantage is that they only can carry a few technicians and a limited amount of equipment (GL Garrad Hassan, 2013).

Despite that there are operators today that are embracing helicopters in the mean that they can cover a larger number of sites faster than work boats, then making it more cost efficient. There are still some uncertainties over how widespread their use can be, mainly restricted to their safety and regulatory implications which have not fully been explored (GL Garrad Hassan, 2013).

2.3.2 Accommodation ships or fixed platforms offshore

Accommodation ships offshore also called SOV (Service Offshore Vessel) or “mother ships” and fixed platforms is a new strategy which will have an increasing influence when the wind farms are moving further out at sea (MacAskill & Mitchell, 2013).
Today “hotel ships” and different types of fixed platforms are used to some extent within the industry for the technicians to remain offshore without going back and forth from the shore base with CTV’s. The main purpose of these is to host technicians, spare parts and repair facilities for a longer time offshore, allowing O&M tasks to be more efficiently conducted and avoiding longer transfer time.

Figure 3 –Ulstein SX175 with X-Stern; SOV Concept for offshore windfarm (photograph courtesy of Ulstein, 2015)

In figure three, a SOV design concept from Ulstein (SX175) with X-stern is demonstrated. This type of vessel can in addition to the gangway capability use small workboats stored on-board for launch and recovery in acceptable weather conditions. In rougher conditions the technicians can access the turbines with special heave compensated gangways maintaining a higher operational window (MacAskill & Mitchell, 2013).
In the proposed Dogger Bank project in the North Sea, where the wind farm site has a planned capacity of 9 GW and will most likely become the world's largest wind farm, located between 125 km to 290 km offshore require new methods for performing O&M duties (Gundegjerde & Halvorsen, 2012).
Due to the location and the exposed area several concepts are analysed and there is a need for the accommodation unit to stay on site for a more effective operation. Helicopters are also a solution that can be available on these ships (Gundegjerde & Halvorsen).

2.3.3 Direct transfer

In direct transfer special designed work boats or CTV's transport technicians to and from the wind farm. These are operating from a port base in close vicinity of the wind farm. The direct transfer is most suitable in scheduled and planned O&M activities but response time and accessibility are often limited by transit time and environmental factors (GL Gerrad Hassan, 2013).
It's the most common method used today but the main limitations come from wave heights and currents, especially wave heights. As the vessels start to move up and down the turbine friction bars, when the conditions become too rough and unsafe for the technicians access the turbine.
Direct transfer can be done with normal mono hull vessels but usually special designed vessels are used. These are less sensitive to waves due to their shape of the hull. The most common used today are catamarans and SWATH (Small Waterplane and Twin Hull). Due to the twin hull design they are more stable in waves and can work in higher sea heights. See SWATH type in table 3 for wave height limitations (Knudsen C et al, 2011).
Mostly fenders are used on the vessel to create friction and prevention of damage on the turbine when this type of transfer is used (Knudsen C et al, 2011).

2.3.3.1 Vessel Concepts – Crew Transfer Vessels

For the majority of the tasks during the O&M phase small supply vessels, or Crew Transfer Vessels (CTV's are used. Normally these can carry 12 passengers and have a load capacity from 1-2.5 tonnes and can proceed in speeds up to 30kn. RIB's (Rigid Inflatable Boats) are also used but only for shorter distances and in good weather conditions. For carrying more heavy equipment like main bearings or a yaw drive a larger supply vessel is required or a so-called Multi-purpose vessel (MPVs), often this is needed when lifting capacity is required (Gundegjerde & Halvorsen, 2012).

In the early stages of wind farm operations local chartered conventional vessels were used as CTV's. However this has changed due to new operational requirements, adoption of new design technology and to increase the comfort for the technicians. An example of that is the SWATH's CTV's, the SWATH technology or design is minimizing the ship's volume near the surface area of the sea. It's in this area the wave energy is located and that maximizes the vessel's stability, even in high seas and at high speed.

Therefore it makes SWATH's ideal in order to increase comfort for the technicians. The different vessel concepts that are available today have mainly been constructed after different kinds of national standards or codes, which can vary from country to country. This adds a dilemma when operators want to employ their vessels in different jurisdiction around in Europe, causing problems with interpretation. Stakeholders and Flag states have asked for a more transparent and uniformed set of regulations and design standards in this segment in order to have a standardize approach to vessel capabilities (Bard & Thalemann, 2011).

For example the classification society DNV has published specifications for wind farm service vessels in January 2011 based upon the High Speed Craft (HSC) Code developed by the International Maritime Organization (IMO). This has been revised and the latest version is from July 2013 (DNV GL, 2013), *Service on wind farms and other offshore installations.* It addresses not only design criteria's. It also includes requirements regarding personnel transfer system, cargo and fuel transfer system and noise and vibrations. .

The specified CTV classes comprise:

- "Windfarm Service 1"-vessels: length < 24 m, transport capacity of 12 technicians
- "Windfarm Service 2"-vessels: length >= 24 m, transport capacity of 13 to 60 technicians

(Bard & Thalemann, 2011)

The crucial aspect for these vessels is the transfer time, which can limit the working time on site, for example slower vessels are not suitable for far offshore working areas (Bard & Thalemann, 2011).
Figure 4 shows speed curves of monohull-, catamaran- and SWATH vessels in relation to transfer time limits given by the wind farm operators. It demonstrates an acceptable transfer time of 60 minutes and 80 minutes as maximum. Further assumptions are based upon average sailing speed of 17 kn for SWATH CTV's, 21 kn for catamaran CTV's, and 30 kn for fast monohull CTV's (Bard & Thalemann, 2011)

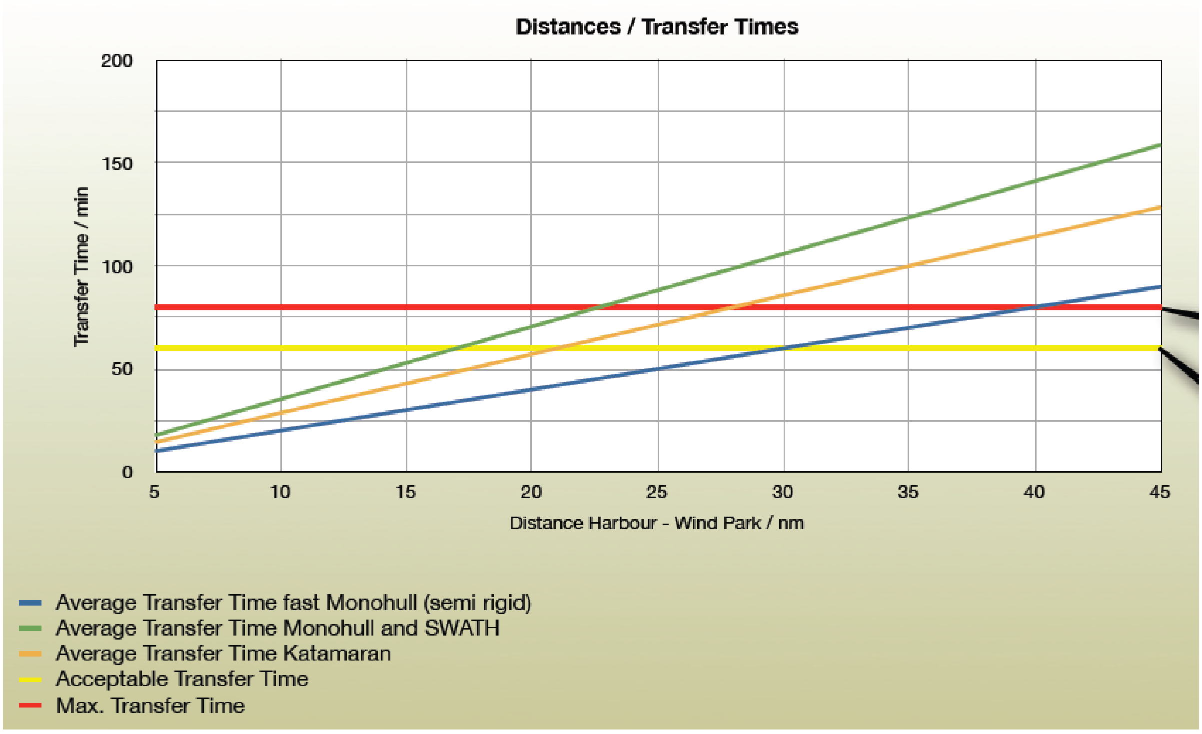


Figure 4– Vessel transfer times and reference times over distance to port (Bard & Thalemann, 2011)

The maximum transfer time limits create a maximum transfer distance of 23 NM for SWATH CTVs, 28 NM for catamaran CTVs and 40 NM for monohull CTVs. A proposed wind farm wind working area of 60 NM offshore no CTV could arrive at site on time (Bard & Thalemann, 2011).
In assuming a daily work time of 8-12 hours and transfer time of 2-3 hours (20-30 knots at a distance of 60 NM offshore) the PROJECT53° calculates with a shore assisted maintenance concept, this will only allow an effective working time of 4-6 hours. (Bard & Thalemann, 2011)This may be insufficient for some maintenance operations and could also affect operational safety due to the time pressure. The solution may be to add higher sailing speeds but with the limiting factor of sea heights a restricted weather window will only be achieved and this not an attractable solution (Bard & Thalemann, 2011).

Another solution is to add a mother ship concepts in these circumstances with the capability of deploying on-board stored CTVs. This could reduce the transfer time significantly to perhaps less than 0,5h and 6-10 h effective working time on site may be achieved (Bard & Thalemann, 2011).

2.3.4 Access methods options

In addition to several different designed boats or vessels, other access options have been developed in an ambition to actively or passively compensate for movements of the waves. These types of active or passive gangways and bridges are usually mounted in the front of the CTV or on the side of a larger vessel allowing the technicians to “walk to work”.
Practice within the industry has been to butt the CTV tightly against the friction bars on the tower and hold it with forward propulsion. This “bump to bump” method works for smaller vessels and lighter conditions with wave height to around and less of 1, 5 m Hs (Marsh, 2013). However as the wind farms move further out at sea and with an ambition of higher accessibility, then a larger operating window in waves up to 2,5m Hs or even more is needed. This creates a demand for new methods of transferring technicians safely to OWTs.

The challenge is to control the 6 degrees of freedom (pitch, roll, heave, surge, sway and yaw) which is the reaction pattern for a vessel that moves freely in the sea as seen in figure 5.

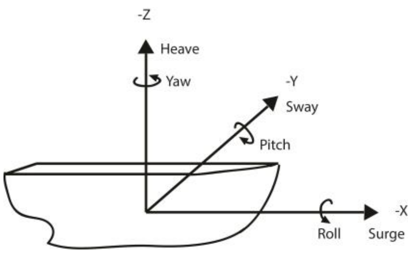


Figure 5 - "6 degrees of freedom", image used with permission (2015)

Depending on which vessel that is in focus, different strategies exist how to control or monitor the degrees of freedom. A CTV could stabilize all motions while pushing on for example. Within this lies a technical challenge and there exists a trade-off between cost and performance. Below are examples of different solutions that exist both actively and passively.

The primary objective is to stabilize all motions for the access point in order to achieve a safe access condition. There are two schools of thought of what approach is the best:

- Active positioning – uses a heave compensated gangway that are linked to a motion reference sensor. Signals of bow motions are then reversed in the access system and the access system actively compensate for the bow motions. For example if the bow raises the access system falls. With this solution the vessel does not need to be connected to the turbine, it can be positioned 10-15m off or more from the turbine with a dynamic positioning (DP) system.
- Passive positioning – Relative motion between the vessel and the turbine tower is accommodated by a mechanical linkage which adjusts itself passively, the main difference compared to an active system. This is done with no servos or control system (Marsh, 2013).

2.4 Operational procedures of crew transfer

2.4.1 Normal conditions

A normal condition intends to describe periods when the projects operate as planned and when sea and wind conditions are on an acceptable level for safe transport and access to turbines. Preferred normal maintenance and inspections are conducted during these periods and interruptions based upon environmental factors are low. This period may last for 65 to 80 % a year depending on area (Dahlén & Jakobsson, 2009).

2.4.2 Extreme conditions

In extreme conditions a safe access to turbines becomes more difficult and even impossible. Access systems may allow boarding and disembarking in levels of 1,5m Hs, however the first and foremost conditions is for systems to function in high amplitude waves but the length of the seas can vary dramatically and affect accessibility with regards to wave heights (Dahlén & Jakobsson, 2009). In some areas like the Baltic Sea and even some shallow parts of the North Sea, the waves may be short and difficult (*Choppy Sea*) despite lower wave heights. Shorter wave lengths makes conditions more difficult than larger.

At some operational sites there exists a strong current. With the combination of strong winds affecting wave heights, could be even more challenging conditions due to the diversity of forces acting upon the access direction and creates difficult docking situations (Dahlén & Jakobsson, 2009).
Even tidal conditions can affect access systems. This requires completely different requirements and needs different types of systems in order to be able to adjust for change in sea levels. Wind farms are not common in icy areas, however there are those how can be exposed to cold environments affecting ladders near the splash zones with ice build-up, hampering accessibility (Dahlén & Jakobsson, 2009).

2.4.3 Industry procedures and guidelines

Within the industry today different types of "best practice" guidelines or procedures exist that address crew transfer from different perspectives. These have been introduced in an ambition to have a common approach for crew transfer. Described below are three different guidelines.

2.4.3.1 IMCA M202

IMCA (International Marine Contractors Association) address in its document M202 boat transfer for the offshore renewables industry, the guidance document also takes up issues that affects different types of transfers in general such as risk assessment, training, responsibility and communication.

The documents states; -"*Transfer of personnel in the offshore renewable industry follows similar principles to that in the traditional offshore construction or oil and gas industries but there are some differences*" (IMCA, 2014) The procedures are quoted from M202:

- *The majority of personnel transfers are made using small vessels of 10m to 30m in length using a 'surfer' arrangement (see section 4.5.1.1);*
- *Crew transfer vessels (CTVs) in the offshore renewable energy industry are generally of displacement less than 500 tonnes and those mating with surfers are normally limited to 100 tonnes due to impact forces on the boat landings. Most boat landings are limited to a static impact force of between 200 and 240 kN and an emergency dynamic impact of 1,000 kN though the specifics for each structure will need to be determined at the time;*
- *Personnel are primarily transferred from a base port ashore or accommodation offshore to the foundation structure of the wind turbine or other renewable energy generator and return at the end of the day;*
- *Depending on the capability of the C T V , transfers are generally limited to 12 passengers, with only a few vessels certified to carry over 12;*
- *The potential wave height in which transfer can take place can vary from location to location. In all cases, it should be demonstrated that the risks identified in section 3.1 have been appropriately assessed and mitigated. The maximum wave height at which transfer is allowable may be increased through use of transfer access systems such as dynamic gangways or active fenders;*
- *CTVs may also carry cargo which can be handled on the forward or after decks using the cranes mounted on the renewable energy structure or installation/support vessels;*
- *Landing areas for personnel transfer by carrier are often small or limited which can impact safe transfer;*
- *Personnel being transferred should be using the appropriate PPE as described in section 3. Additionally, personnel should have received appropriate training in*

climbing and, according to the on-location risk assessment, be wearing immersion suits that are suitable for climbing. (IMCA M202, 2014)

The document also addresses risk assessment as a tool, irrespective of transfer method and should be carried out beforehand, the risk assessment could be completed as a part of the daily safety briefing or toolbox talk (IMCA, 2014). The assessment should address issues such as environmental conditions, vessel motions (Pitch, Roll and Heave), seaworthiness, training of involved personnel and a lot more (IMCA, 2014)

2.4.3.2 Good practice guideline – G9

The G9 Offshore Wind Health and Safety Association (G9) consists of nine of the world's largest offshore wind developers, who have jointly come together to focus on important issues related to health and safety within offshore wind industry. This document "The Safe management of small service vessels used in the offshore wind industry" is produced as a part of that work and was published in November 2014.

It addresses issues such as site management, marine coordination, marine operations, vessel management and it also contains some annexes. In chapter 4 marine operations are addressed and particularly passenger transfer to wind farm structures. In chapter 4.2.2 the following is extracted:

..The Transfer Assistant should:

- *conduct visual inspections of the ladder, transfer area, boat and structure fendering;*
- *conduct pre-use checks of the Self-Retracting Lifeline (SRL);*
- *conduct pre-use checks of any personnel transfer system in use, and*
- *notify the Master on satisfactory completion of the checks.*

The Master should authorise personnel transfer based on:

- *the motions of the service vessel;*
- *the prevailing environmental conditions, and*
- *the stability of the connection between the vessel and the structure.*

Vessel motion monitoring systems may be fitted to assist the Master in judging the appropriate conditions for a safer transfer.

Once the Master has authorised transfer from the vessel, the Transfer Assistant should:

- *call the first transferee forward to the transfer area;*
- *check correct use of PPE by the transferee;*
- *pull down the SRL and assist the transferee in attaching it;*
- *stand back from the transfer area and observe the transfer when the transferee is clear of the vessel and*
- *notify the transferee and the Master of any potential hazards observed during the transfer.*

When recovering passengers to the vessel, the Transfer Assistant should:

- *count down the remaining rungs of the ladder to the transferee and inform the transferee when it is safe to step across to the vessel;*
- *assist the transferee back onto the service vessel, and*
- *assist with disconnection from the SRL*

(Energy Institute G9, 2014)

Limiting weather criteria
The Guidelines also address weather criteria and it lies with the responsibility of site management to establish limiting weather criteria for all marine operations that are to be under taken in the windfarm, these should include but not be limited to:

- Significant and maximum wave heights
- Wind speed and directions
- Peak speeds and direction
- Peak and mean wave periods
- Current strengths and directions and tidal ranges

The vessel specific limiting criteria should involve the service vessel and its motions in different weather conditions and be referred to the operating limits defined by the vessel operator or class documentation. Concerning any marine operation, the limiting criteria should be defined covering the whole operation and the master, marine crew, passengers and marine coordination should understand and have knowledge about these values.

In addition to limiting criteria site management should also define marginal criteria for all operations undertaken in the wind farm. As reference the marginal conditions should be less than the limiting. The responsible marine coordinators should monitor current and weather forecasts and inform any service vessel involved in a concerned wind farm if the criteria of the forecast are to be exceeded during the operation (Energy institute G9, 2014).

2.4.3.3 The Renewable UK

The Renewable UK address in its publication *Vessel Safety Guide Guidance for Offshore Renewable Energy Developers* (2012) the issues with Sea states and Weather forecasts as essential in order to carry out activities in a safe manner and states the following:

- *The weather limitations of the activity need to be determined taking into account the site and duration of the work;*
- *The selected vessel must be capable of operations within the expected prevalent conditions with a safety margin to allow for changes in environmental conditions;*
- *The assessment of weather conditions should include the time to transit to/ from the site and distance from a safe haven;*
- *A common understanding of the limitations of the vessel between all parties is essential;*
- *Site specific and up to date weather forecasts need to be reviewed to allow planning of the operation;*
- *Local weather, wind, tide and sea state characteristics and other applicable metocean data must be taken into account at the time of carrying out the activity;*
- *Local conditions should dictate when operations are safe to continue;*
- *The environmental conditions should be below the limits set within the risk assessment and procedures for the activity.*

(Renewable UK, 2012)

In the document *Offshore Wind and Marine Energy Health and Safety Guidelines* (2013) Access and egress procedures are highlighted. The standpoint is that every transfer exposes the people involved to a number of significant hazards. With regards to expected frequency of transfers, extremely robust and repeatable systems are required in order to ensure that the overall risk remains at a tolerable level and states the following (Renewable UK, 2013)
The following part has been retrieved from chapter C in that document.

C.1.2.5 MANAGING THE RISKS

A wide range of factors that could affect the risk to people transferring from vessels needs to be considered:

- *Any access system needs to have a clearly-defined operating window, supported by robust evidence of capability relative to metocean condition limits such as:*
  - *Wind speed and direction;*
  - *Sea state - wave height (significant and maximum), direction and period (which combines with height to affect steepness);*
  - *Visibility □ fog, hours of darkness;*
  - *Effect of tidal height and currents;*
  - *Sea temperature;*
  - *Air temperature, as very cold conditions, combined with rain or sea spray, can cause icing on ladders and fall arrest systems;*
  - *Uncertainty in measurements or variations across a site;*
- *Site characteristics, such as the distance to the onshore base or safe haven, will affect routine and emergency planning arrangements;*
- *Structure to be accessed:*
  - *Orientation of access point(s) relative to prevailing metocean conditions;*
  - *Design of interface:*
  - *Structural strength;*
  - *Compatibility with vessels, including maintaining a safety zone so that the person on the ladder cannot be injured by vessel movement relative to the ladder;*
  - *Condition of the interface at the time of transfer, such as damage / deterioration, and contamination;*
  - *Guano presents a range of health risks, including the potential to aggravate respiratory disorders such as asthma; Relative movement of floating OREIs, or accommodation vessels, against access vessels, in response to the sea;*
- *Access vessel:*
  - *Capability relative to metocean conditions;*
  - *Skill and experience of crew(s);*
  - *The manner in which it interacts with the landing system, for example, whether it moves under a stick-slip friction regime, or gradual release;*
- *Human factors:*
  - *Pressure (from any source, including oneself) to get the job done:*
  - *Frustration if unable to transfer after long journey to site;*
  - *Wanting to get off vessel after journey in rough conditions;*
  - *Not wanting to be stranded, even if conditions have deteriorated whileon the offshore structure;*
  - *Financial incentives for offshore working;*
  - *Ability to make objective safety / capability assessments prior to a transfer, particularly if cold, wet or suffering from seasickness;*
  - *Fatigue, due to factors such as long working hours, intensive campaigns, or long transit journeys in rough sea.*

(Renewable UK, 2013)

2.5 Training and competence

The training standards for the marine crew for CTVs are dependent on their size and passenger capacity. Normally these vessels are only certified to take maximum 12 passengers along. These requirements then formulate the competence level needed for the marine crew. The STCW (Standard of Training and certification and Watch keeping) addresses these issues on larger vessel normally above 500 GT.
For the wind farm support vessels often different local or national rules apply like the British *Large Commercial Yacht code (LY2)* for masters on yachts up to 200 GT (MAIB, 2013).

There has been a lack of a uniformed standard across the industry however the focus has changed and this ambition is address in several guidelines and IMCA are presently working on a competence standard for masters and deck crews. A key element of a master on a CTV is navigation, boat handling and manoeuvring close to turbines; often the master and his training are focused on these types of skills (MAIB 2013).
In the accident report by the MAIB (2013) involving the vessels "Windcat 9" and "Island Panther" which collided on two different occasions with two different floating targets (the different accidents are covered in the same report) lack of competence standards and training is highlighted as a contributing factors, it states: *"There is little relevant industry training available for masters and crews of PTVs"* (PTV – Personnel Transfer Vessel), (MAIB 2013). It's further on mentioned that one training provider offers an introductory half-day course which includes lectures and practical exercise in manoeuvring a PTV to dock with a turbine foundation.
The reports also highlight a need for marine operational guidance to owners/managers and crews operating PTV's. Another conclusion addresses the issue that often the masters are coming from the fishing industry and they are not used to operate high speed transfer vessels and it's important to focus on correct and continuous training.

There are challenges in the development in identifying and agreeing upon relevant training standards throughout the industry, and should be considered to be an industry good-practice framework for stakeholders to work towards. These are not mandatory industry standards but to be seen as guidelines. (Renewable UK, 2014).

2.6 HSE – (Health, Safety and Environment)

Safety is defined as the freedom from those conditions than can cause death, injury and occupational illness, or damage to or loss of equipment or property (Standard Practice for System Safety, 2000). Most of the time the offshore wind farm is unmanned, therefore health and safety issues only concern the installation, maintenance and decommissioning processes (Dai, 2104). There are guidelines in place who address different aspects of the operations in place, despite that there has been seen a high number of incidents (see chapter below) associated with different operations such as; crane and lifting operation during installation, heavy maintenance work and access to and egress from OWTs (Dai, 2014). Many lessons can be drawn from similar industries such as offshore oil and gas which is much more mature with regards to HSE. The offshore oil and gas industry has a strong focus on avoiding collision between service vessels and offshore installations. In the offshore wind industry, as Sharples and Sharples (2010) indicate service vessels colliding with OWT's are realized as a potential threat, but has not given much attention by designers and operators.

On the other hand several studies have addressed the issue of passing vessels engaged in other marine activity colliding with OWTs and the associated risks (Dai, 2014).

2.6.1 Incident Reporting

Between January 2011 and September 2012 DNV GL conduced a review of the G9 incidents categorised under “Marine operations and “Personnel transfer” in an attempt to identify trends or specific high risk operations.
Marine operations and personnel transfers in general were identified, as areas where significant risk applied, seen below is a table 4 of reported incidents:

Table 4 – Reported incident activity (Compiled from the Energy Institute (G9), November 2014)

Activity Category	Comment	Incident count	% of total reports
Crew or personnel transfer	All incidents involving transfer of boat crew or other personnel.	27	16
General	Incidents in which the specific activity is not important. The Hazard represents a general on-board condition or is related to general voyage.	24	14
Installation operations	Installation of equipment at wind farm.	18	11
Deck activities	Non-specific activities involving the presence of personnel on the deck.	14	8
Mooring	Incidents taking place during mooring operations.	11	6
Maneuvering	Incidents involving boat maneuvers within a wind farm or in the immediate vicinity of an asset (excluding personnel transfer)	8	5
Anchor operations	Incidents during anchor operations.	6	4
Jacking-up	Incidents during jacking-up	5	3
Housekeeping	Reports involving failure to follow housekeeping procedures.	5	3
Jetting	Incidents during jetting.	4	2
Deck cargo	Incidents involving deck cargo. Usually failure to secure cargo.	4	2
Sum		**126**	**74**

Regarding the incidents crew and personnel transfer has the highest number involving 16% of the total reports of all the incidents where it was possible to determine an immediate causal factor, 46 % of these were linked to a failure to follow procedure.

Further incident data have been collected for the year 2013 and was published in 2014. It again identified small craft vessels and crew transfer vessels in particular involved in significant number of reported marine operations incidents (Energy Institute (G9), 2014).
In the report 616 incidents were reported, 131 of these occurred during marine operations and 281 of the 616 occurred on vessels.

Figure 6 demonstrates incident regarding vessel breakdown and illustrates a high number of incidents for un-classed vessels, often these vessels are the CTV’s as these are not covered by class rules.

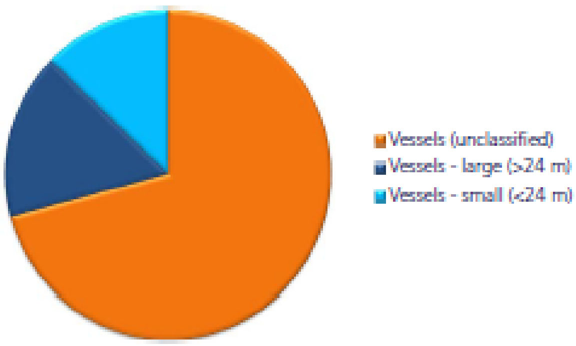


Figure 6 – Vessel incident break down (Energy Institute (G9), 2014)

Regarding marine operation the below figure 7 illustrates different incidents related to that area.

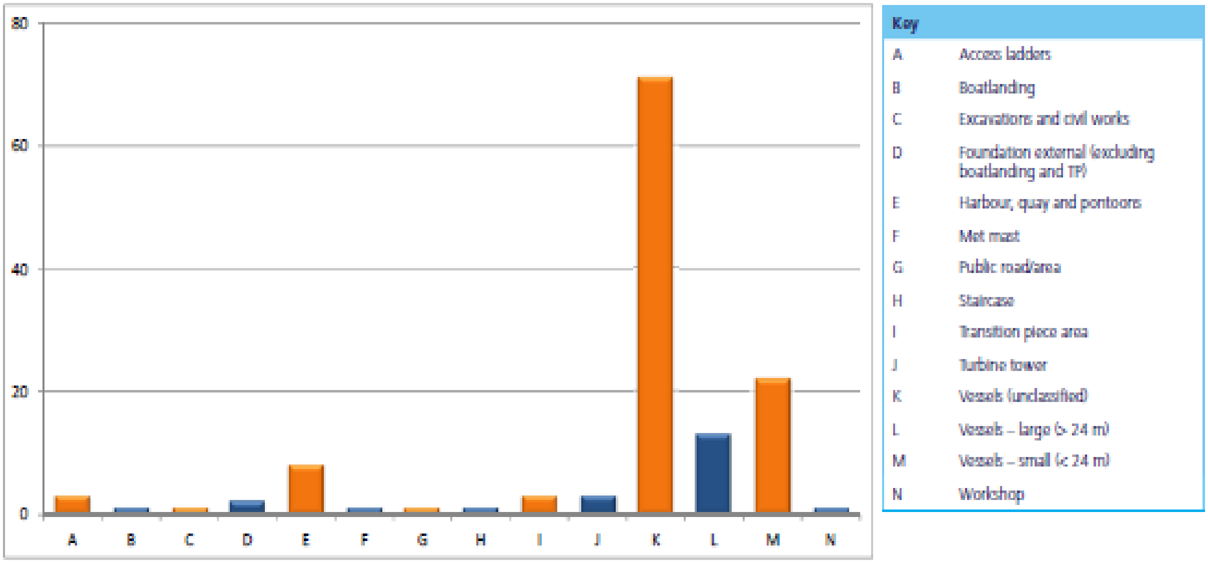


Figure 7– Marine operations – incident breakdown (Energy Institute (G9), 2014)

Total incidents were 131 and 106 of these occurred on the vessel them self with the highest rating for unclassed vessels.

The annual incident data report from 2014, reveals again marine operations as a high risk area, 228 incident occurred during these activities, the majority of these (159) occurred on the vessels them self. Those connected to “transfer by vessel” were 44% (Energy Institute (G9), 2015). Seen below in figure 8 demonstrates incident data breakdown and as for the year of 2013, vessels below 24 meters still have the highest number of incidents.

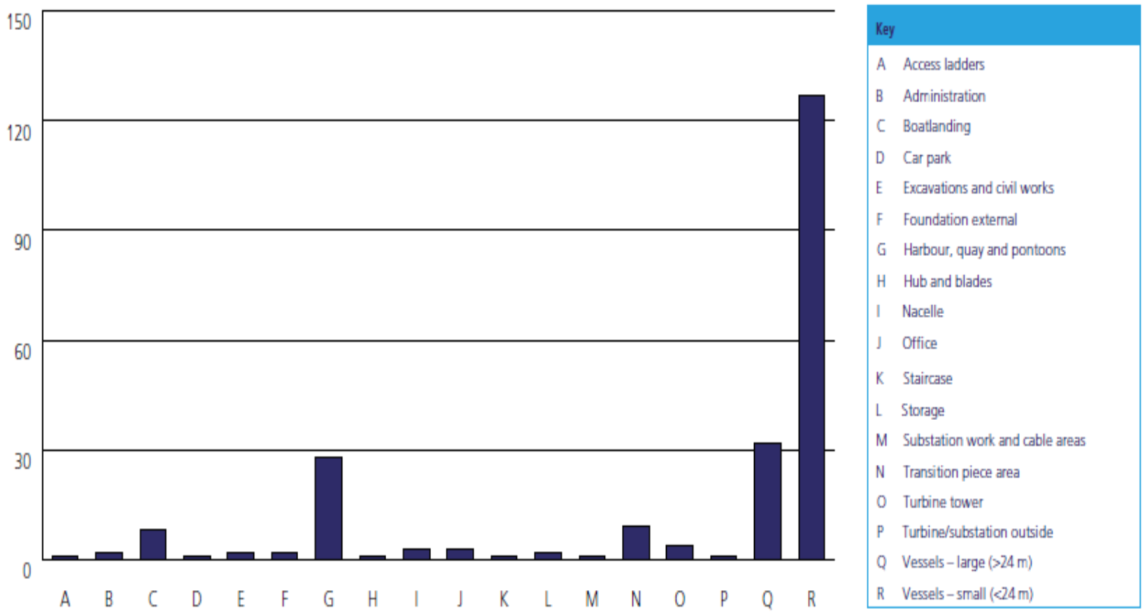


Figure 8 – Marine operations – incident area breakdown (Energy Institute (G9), 2015)

3 METHODOLOGY

This thesis has a qualitative research approach and containing mixed methods as a mean to answer the research questions.

3.1 Mixed methods

The term “mixed methods” refers to research that combines alternative ways of data collection in a specific research project (Descombe, 1998). Two different methods have been used in this thesis; semi-structured interviews and a hierarchical task analysis (HTA) as a result of an on-board observation of a CTV operating in a wind farm.
Mixed methodology gives the researcher the opportunity to verify the result from one method with the result from another and when different methods are providing the same result, the researcher may be able to argue for a higher level of validity. The data from different methods can also be used to complement each other and by combining different perspectives a more comprehensive result can be provided than an approach only involving one method (Denscombe, 1998). In addition, with insights of positive and negatives sides of both methods, the combination of two might compensate for weakness in one and possible critics arising due selection of only one can be met (Denscombe, 1998).
Mixed methods can also be used to bring the analysis forward, where one method can provide information that can be used in another; in this case you use an alternative method to develop the information that has been produced by the first one.
However using mixed methods doesn’t say that “everything is allowed”, there has to be a clear ground and motivation to use mixed methods, in the same way mixed methods are not applicable on all research areas Denscombe (1998).

3.2 Grounded theory

Grounded theory is an inductive and theory generation approach and does not test hypothesis as mainly normal research does (Denscombe, 1998). Grounded Theory is relevant when empiric fieldwork is required and when there exists a need to create theories from practical situations that exist in the reality. The primary objective is to develop the theories based upon high amount of data collected from the “field” or reality.
The characteristics of grounded theory are to develop theories based upon the data in a constant process where the ideas always are verified against the existing data. The theories that arise should be improved through additional testing against data which is collected for this purpose (Denscombe, 1998).

3.3 Data collection

The data is collected from the two methods described below.

3.3.1 Interviews

To provide a foundation for analysis of the research questions, semi-structured interviews were conducted. In addition semi-structured interviews were also conducted as a part of the on-board observation for better a standpoint in the analysis and verification of the procedures. The selection of informants is important with regards to purpose and research questions.
For this method; shipping companies, wind farm operators and a classification society were selected as the most relevant stakeholders as they represent different perspectives:

- Wind farm operators – They are responsible for the wind farm to produce electricity, and by that the operation and maintenance phase.
- Shipping companies – They are responsible for the vessels, the management of these and operation.
- Classification society – These organisations are responsible for vessel classification and approves vessel after construction. They are also responsible for classification of wind turbines and some of these does also provide operational guidance for marine activities.

Concerning the classification society, two interviews were conducted as the first informant recommended an additional interview with a person that was more experienced and had further knowledge in these matters. Altogether six interviews were conducted and they lasted for 45-60 minutes each.
The type of interview selected was semi-structured, as the importance was to get the informants to develop and share his/her depth knowledge and express more experiences in the subject. All informants were giving the same set of questions represented in Appendix A and received the questions in advance for better preparations, understanding of the contents and relevance of the interview. A face-to-face interview was conducted with three informants and due to different circumstances with large geographical separations, three interviews were conducted by telephone. The interviews were recorded and later on transcribed

According to Kvale (1997) preparation is vital and the key questions is *what, why and how*; *what* – to get the relevant knowledge of the area before the interview; *why* – to have a purpose with the interview; and *how* – selection of the most suitable interview method.

Therefore the interviews were organized according to Kvale's (1997) "seven stages":

1. **Thematiation** – This involves the formulation of the purpose of the research and a description of the content before the interview parts starts.
2. **Planning** – Planning and preparation of the seven stages in the investigation and how and when the interviews will be conducted.
3. **Interview** – To carry out the interviews.
4. **Transcription** – Preparation of the interview material for analysis which involves transcription of recorded material into text.
5. **Analysis** – Selection of analysis method in relevance to the purpose of the investigation and subject.
6. **Verification** – Establish the degree of validity and reliability
7. **Reporting –** To report the result of the investigation and the methods used.

In addition Kvale addresses two main aspects in this; *thematic and dynamic*. *Thematic* - is the creation of interview questions in relation to the subject and the research question, the acquisition of knowledge. *Dynamic* – involves the ensemble between the interviewer and the informants. A good interview question should contribute thematically of knowledge production and dynamically with creation of human connection.
Kvale highlights this relationship and ensemble for the best outcome, which where an important part of the interviews.

3.3.2 Hierarchical Task analysis (HTA) - On-board studies and observations

The second method used was a hierarchical task analysis (HTA) which was conducted on a CTV, participating in this type of operation, primarily transporting technicians and cargo to and from the wind farm.
The observation was conducted on the bridge of the concerned vessel covering: navigation to field, different approaches to different turbines/floatels/substation and a cargo operation at a sub-station was also observed. The importance in this method according to Decombe (2009) is being part of the concerned environment and conditions and this enables a deeper understanding of specific activities in a defined task.
In this observation the author's identity was known to all participants on the vessel that day, technicians and the crew. This allowed the author to experience the operational environment, the tasks being performed and learn about the conditions, vital aspects according to Descombe (2009) for being able to analyse the observations with the right background. The data recorded was later on used for creation of the HTA.
The stand point of the observer was mainly to be "out of the way" and when necessary record conversations and the operations that were vital for the observations. In using video- and audible recordings the vital parts of the observation was documented.

3.3.2.1 Conditions

The on-board visit/observations took place on a CTV which was chartered for a recognized wind farm operator; performing its duties in a wind farm 50 NM outside the west coast of Denmark. On that day for the observation there were eleven technicians coming out for conducting different duties in the wind farm. The conditions were; easterly winds around 20-25 knots, the wave height in the morning when arriving the field was Hs 1,5-1,7 m and maximum wave height around 2-3 meters slowly reducing.

3.3.3 HTA

Hierarchical task analysis (HTA) is a method to describe tasks. The HTA identifies and characterizes the fundamental characteristics of a specific activity or a set of activities by observing what an operator or a group of operators need to do to achieve a given goal (Hollnagel, 2006). The method is widely spread and used in several different domains such as air traffic control, product design and nuclear domains as a few examples. The HTA is the natural step after a collection of data and provides a step-by-step description of the activity under analysis. The analysis breaks down the task into a nested hierarchy of goals, operations and plans. The advantages with using the HTA are, that it is a quick method to implement and requires minimal training and equipment to get a description of a complete task. With pen and paper one can easily perform an HTA.

3.3.3.1 Procedures

The performing of an HTA according to Stanton, *et al.*, (2006) are divided into six different steps that are described below:

1. Performing an HTA is to define the task that is being analysed. The purpose of the analysis should also be defined. In this report the HTA analysis CTV operation, all relevant tasks and subtasks performed by the crew, and as well identify tasks with higher complexity.

2. The data can be collected in many ways. For the HTA in this report the data collections were conducted with on-board observation, interviews and Video/Audio recordings.
3. Is determine the overall goal of the task. This determination is the top of the hierarchy in the analysis. In this report the overall goal of the task is to describe CTV operation.
4. The overall goal is divided into task sub goals, the sub goals together should form the tasks required to reach the overall goal. Sub goals in the HTA in this report is for example planning of the operation and execute a safe and efficient transfer to a wind turbine.
5. The sub-goals are divided into sub-goals themselves. This is done until it cannot be done anymore and the bottom level of the HTA is reached and the operation is fully described.
6. The planning of the analysis and should describe how the goals are reached. A simple plan would say do 1, then 2, then 3 and when it is completed return to the super-ordinate level. Example: for planning the operation perform these operations and then return to the next step that comes after the planning the operation.

3.3.3.2 Interviews as part of the HTA

For better understanding in the analysis and for a better verification on the analysis made, interviews were conducted with two masters working on a CTV. Another set of question were used as seen in Appendix B compared to those used on the other informants.
The interviews were semi-structured, as this allows the master(s) to be more explorative in the answers in sharing their experience and knowledge in this subject and providing further insights that was usable when making the task analysis.

3.3.3.3 Review

The Analysis has been reviewed by two captains; the on-board captain and one from another similar company and the comments have been used as update on the HTA. Only small adjustment was needed due to this and no change of the colour coding was requested.

3.4 Ethics

All informants in the interviews were asked if they accepted that the interview was recorded and that they could stop the recordings anytime if they felt uncomfortable with the situation. Their identity is kept confidential with regards to statements in the result sections, and there categorized as informants A, B, C, D, E and F. In the observations a “Participant Consent Form” (Appendix C) was used for the marine crew to get their approval for the recordings, the technicians were also informed about the observation.

3.5 Data Analysis

The data analysis has been conducted using two steps, first each of the primary data collection methods.

3.5.1 Interviews

To analyze that amount of data from the interviews a categorization or concentration of different contents in the interview is required. The main approach in this analysis was to use “sentence concentration” to reduce the amount of text.
According to Kvale (1997) the transcribed text are concentrated to smaller statements where the most important contents are mentioned by a few words.

The analysis has used five steps defined by Kvale (1997) as an approach to formalize the contents of the interview to a result:

1. Reading of the whole interview was conducted, to be able to have an understanding of the totality.
2. The different sentences were contextualized as expressed by the informants.
3. This step involved the formulation of the different themes as simple as possible; the standpoint here was to interpret the expressions in the interviews with no subjective judgment and organize them into defined themes.
4. This step compares the different themes against the research questions and organize them dependent on the content.
5. The final step is to contextualize all themes relevant to the research questions in a formative text description.

3.5.2 HTA

In the HTA, the complexity of the single operations was of relevance. To denote the complexity of a single task a colour coding of the HTA-tree cells was chosen. The colour represents how complex the task in the box is to perform. Since the HTA is an analysis of a standard operation with no errors, the colour also shows tasks that can go wrong and that might lead to complete other tasks needing to be performed. In that case it can also be demanding and increase the workload demands on the crew. The level of complexity was created by author upon his own assumption and previous experience working with offshore activities but with other types of vessel in demanding operations.

The following colour coding has been chosen:

- ***Black framed tasks*** *represent tasks with low complexity , none-demanding; like planning and preparation.*
- *The yellow framed tasks demonstrate that the crew has to pay attention. It can be when the captain is communication with other vessels or technicians in the wind farm or navigating to the field or infield between the turbines.*
- ***The orange*** *framed tasks represent tasks with a higher mental workload which require larger concentration. Typical tasks marked orange are where the bridge coordinates the operation with the deck crew or the technicians, and the same time as the bridge, captain has to keep the vessel in position and perform other tasks, or navigating in high traffic areas or in reduced visibility.*
- ***The red*** *framed tasks with the highest workload and focus. During these tasks the crew has to be very observant on what they all are doing and often involves risky situations where mistakes easily can lead to accidents. Deck crew working on the deck in a cargo operation is such a high complexity (and very risky) situation.*

4 RESULTS

The results are divided into two parts; one about the result from the interviews and one addresses the result of the HTA.

4.1 Results from the interview investigation

The analysis of the interview has been divided into three areas with the following subareas:

1. Challenges for the wind offshore industry
2. Near-shore and present situation
    a. Operational limitations and challenges
    b. Procedure and access systems
3. Remote offshore wind farms and future perspective
    a. Operational limitations for O&M
    b. Development of access systems

4.1.1 Challenges for the wind offshore industry

On the first question all informants mention one word as a main challenge and that is “cost” in general and that is not only related to the O&M phase but also for the wind offshore industry as a whole. The industry needs to be competitive in the future in supplying an acceptable cost of energy for the electricity market

According to the informants the industry is comparatively new, the wind farms have become bigger and further offshore. A reasonable fast development and the transfer from learning and experience in many areas like technical and even operational into new projects, is sometimes difficult which drives the costs upwards. As mentioned by one of the wind farm operator – *“That is something that we have now the first generation of wind farms and we have very high costs during the project and also now during the operation, we have get experience and get costs down”* (Interview C, 2014-10-23) The issue of experience which needs to be improved in the industry was addressed by all.

Lack of standardization throughout the industry is another perspective that was addressed by all, and this issue can be viewed from different areas like: boat landings, design of turbines, harmonized procedures for marine operations and even on large scale concerning construction of a wind farm. The quick technical development on for example wind turbines have led to no scale effects, and addressed by the classification society “*the development cost for development of larger turbines must be taken on the price which makes it more expensive. If this development stops on 8 MW turbines, if you standardize this and the produce on large scale then you will receive volume cost benefit”* (Interview E, 2014-12-18)

A more developed standardization needs to be implemented in all areas from construction to the O&M phase in order to increase the efficiency across the industry. (Interview E, 2014-12-18)

Another issue that was mentioned by all was that remote offshore wind farms will have another and different type of operational environment, with rougher conditions and longer transfer times. However the answers differs in how this will affect the industry; the windfarm operators addressed this as a cost driver that needs adopted maintenance strategies to overcome this.

The vessel operators see this development as a change that will require another approach in vessel development adjusted to the operational requirements, as mentioned by one vessel operator: *“you can’t provide a more outstanding vessel and crew for less cost”* (Interview B, 2014-10-14)

This can be viewed from another perspective which was mentioned in Interview F (2015-04-15) and address the challenges in remote offshore wind farms;
"*With current access methods there would be around 200 days access (at 1.5m Hs limit) for UK Round 3 sites* (Remote offshore, authors note). *Most existing sites aim for around 300 days access, so a drop to 200 in Round 3 would simply not be practical in the sense of number of days a year that the site can be accessed by vessels. UK round 3 sites which includes Dogger Bank but also some of the bigger sites near shore, you can't keep a farm operational with that level of accessibility"*.

In addition both wind farm operators and one vessel operator mentioned political support and a harmonized legal environment that supports the ambition for a better utilization of renewable energy in the future, that requires more cooperation on national and European level in creating clusters, that must be considered as a necessity when going further offshore (Interview A, 2013-10-14)

4.1.2 Near-shore and present situation

4.1.2.1 Operational limitations and challenges

The main operational challenges that provide the limitations in crew transfer is environmental conditions on site and on transit with focus on wave heights and local characteristics from currents. A limitation value of 1.5 m is mentioned by four informants, which is considered as an industry standard for crew transfer (Interview B, 2014-10-14). One wind farm operator also mentioned 1.2 m Hs a limit which the technicians feel more comfortable in (Interview A, 2013-10-14). However one vessel operator and also confirmed by the classifications society address 1.75m up to 2m Hs as limits for larger and more powerful CTV's with good quality fenders. One wind farm operator however believes it's difficult to conduct boarding above 1,5m, often local environmental characteristics are crucial for the ability. Often the access points are located in the direction of largest waves but that can be a problem in areas where there exist a strong current, like the Irish Sea and even in some sites in the North Sea. Strong current can have more impact on the vessels then the wind, as expressed in interview A (2013-10-14); "*in a project in the Irish Sea, they have had serious problems with this and the current moves around 4-5 knots through the field. Here they misjudge the current and only consider the wind when they place the access points"*.

Another important aspect in the limitation of CTVs is the response time and distance to shore in relation to operational window and efficiency. This was mentioned by 3 informants. Highlighted by the classification society, the access limit in Hs, becomes less relevant if the response time is reduced.
The classification society also mentions response time in relation to different capabilities of CTV's. CTV's(less than 24m) with a step over transfer method works in probably up to 15-20 NM from shore. In the span of 20-30 NM from shore they addressed a mixed method approach using both helicopter, "larger walk" to work vessel assisted by gangways and in addition; CTVs. Going above that; -*"the transfer time become more critical and become really important and that's the limit in the use of the small service vessels"* (Interview F, 2015-04-15).
However a 50 NM limit offshore was also mentioned as a maximum limit for CTVs. Then the distance has the largest impact on O&M costs, due to the amount of fuel used and the time the technicians are on transit which significantly reduce the activate time on site (Interview E2, 2015-04-15). Both wind farm operators address this aspect in relation to the Butendiek offshore wind farm, which is 29 NM from the coast (Authors note), where preparations are

established on the turbines to facilitate “walk to work” assisted vessels, normal CTV’s and also helicopters

Another challenge that was mentioned by all was training and experience for the technicians. The vessel operators also mentioned this issue in relation to the marine crew. Often the technicians are not “offshore guys” and their experience from offshore activities varies from site to site. Working in an offshore environment compared to an onshore environment require more training and experience. From a safety perspective that is vital.
One vessel operator mentioned that they ask the technicians when they come on-board on experience level, which they normally confirm. In an access situation where the vessel is pushing on to the turbine, they have experienced that “people do freeze” and that’s a safety risk when the weather situation is marginal (Interview B, 2014-10-14). They would prefer some type of traffic light system based upon the experience level of the technicians. The workability and performance of the technicians can also be viewed from a seasickness perspective, which is a large problem in these operations. The conditions of the technicians’ ability to perform their duties safely are vital and that might require more technicians in worse weather to perform a specific maintenance tasks. (Interview A, 2013-10-14).

Both wind farm operators mentioned this a driver for expensive access solutions; *“The way of solving that is to apply more technology but not focusing on getting the right people and train the people to be able to cope with the offshore environment, there is a big challenge”* (Interview C, 2014-10-23). Also one vessel operator and the classification society address the existing technical solutions of access options (active/passive gangways) as an area where additional development is needed for increased operating windows of CTVs. This is summarized by one vessel operator;

.
If you got well-designed vessels which reduce vertical movement and you will increase the transfer height, if you got an experienced Captain/crew and the technicians got confidence in everybody onboard you have got a good setup, not by pushing the boundaries but got better confidence in transferring in larger wave heights. (Interview B, 2014-10-14).

Vessel design is another influencing factor on vessel limitations. The introduction of SWATH’s and semi SWATH’s, where the design of the hull can increase the vessels ability to transit in higher sea states, provides a higher degree of comfort for the technicians and prevents seasickness (Interview E2, 2015-04-15). Both vessel operators and the classification society confirms above opinion. However as the parameters and tasks for an O&M vessel are constantly changing it’s becoming more important for the CTV to carry cargo for instance and not just focusing on crew transfer. The multi-purpose capability will become more important in the future. All informants confirm this issue.
For the SWATH vessels that could be a limitation as they are quite weight sensitive for in their performance. In the ambition to develop the utilization of the CTV to become more multipurpose and highlights the challenge to find the right balance between crew and passenger comfort and possible cargo capacity.
According to one vessel operator who addressed “day rates” as a limitation for vessel development, -*“now we are looking into vessel design in fine details to try increase transfer height but not increase the day rate”* (Interview B, 2014-10-14).
In the opinions of the vessel operators higher day rates could actually increase vessel limitations as design of vessel could be adopted against operational needs. On the other hand the wind farm operators are more concerned about increased costs.

4.1.2.2 Procedure and access systems

The wind farm operators mentioned different logistical solutions that are available today in relation to their demands on accessibility and availability, these have to be cost effective and fit for purpose. According to one wind farm operator; *"We demand 95 % of availability guarantee from them (Wind turbine manufacturer:, Authors note), then it's they who need to think depending on environmental circumstances on choices how we can get accessibility that creates 95 % availability"* (Interview A 2013-10-14) The manufacturer is then responsible to establish a logistical infrastructure or a adopted design on the turbine that can provide that level of accessibility. Both wind farm operators address different concepts available today like accommodation platforms, helicopters and CTV's, but the challenges remain how to operate these independently or combined for the O&M phase for an acceptable level of accessibility. One wind farm operator question the ambition for improved accessibility if it's economically feasible by implementing other design or technical solutions in for example adding additional boat landing(s) on the turbine.
With regards to procedures, the vessel operators and the classification society address the most common access method and its procedures, traditionally its "bump to bump" that involves the majority of all access situations for CTVs.
According to Interview B; *"if the vessel moves 2 runs on 80 % we cannot move on 100% and if it's an increase of forecast, we can get to the point that we put the passengers up and we know that we move 2 runs at 80 % and if the forecasts is increasing we may end up to 100 % and moving still. That's the role of thumb".* That works for most vessels up to 1.5m Hs (Interview B, 2014-10-13)

That highlights the issue of fenders which add affects the capacity of a vessel to be stable on the access point while pushing on, as mentioned by the classification society: "*For ex a 15m vessel with a poor designed fender and a larger vessel 20m with a very capable fender and comparing performance between a smaller CTV and a larger, the smaller vessel become dangerous to operate in limits around 1.2 and the larger vessel can operate in 1.5 and even up in waves closer two 2 meters"* (Interview F, 2015-14-15).
The efficiency of different accommodation vessels (OSV's/SOV) with heave compensated gangways was questioned by all and today these concepts with its performance are quite time consuming as these vessels need to setup for each turbine and conduct the transfer. One vessel operator mentioned; *"The gangway system needs also to be developed on the SOV's, today the objective is 15 min from turbine from turbine but the reality is more modest with 35-40 min now and it takes too long time"* (Interview D 2015-04-14).

Two of the informants also mentioned ribs as another solution for more effective utilization and distribution of technicians. However due to the stronger safety focus within the industry that may be prevented. There exists a push to introduce defined limits on safe transfer and to establish clear rules for it and take away the subjectivity in the judgement of the masters (Interview E2, 2015-04-15).

4.1.3 Remote offshore wind farm and future perspective

4.1.3.1 Operational limitations for O&M

All informants agree that going further offshore will become more difficult due to the increased environmental conditions. The informants also address the transfer time as more critical due to longer distances from shore. A concern especially among the wind farm operators highlights a predicted increase of cost with these challenges as other transfer concepts, logistical strategies and technical improvements will be are required. Especially the environmental conditions will have the largest impact that will create different capabilities and also restrictions for some logistical concepts. The response time on the other hand will at the same time challenge the degree of efficiency and limitations for the different solutions used. One of the wind farm operators highlights the challenge with maintainability, if it's planned or un-planned maintenance. They require that the constructions are dimensioned for one maintenance occasion per year. However the reality has demonstrated the difficulties. "*It's the unplanned maintenance that cost a lot of money for one job."* (Interview A, 2013-10-14) The same operators also mentions that; "*In the short term, the remote wind farms will make things worse regarding the availability, in the long term you might have learned that making things that are more stronger and you can make this systematically.* (Interview A, 2013-10-14) Also one vessel operator address these issues from another perspective which may have an impact on maintainability, that rougher conditions will require more robust designs of turbines.

4.1.3.2 Development of access systems

The informants agree that remote offshore wind farms will require another type of logistical model and strategy in covering duties related to the O&M phase in obtaining an acceptable level of accessibility. This may involve different concepts of SOVs and mother-ship solutions with heave compensated gangways, accommodation platforms, helicopters and larger CTV's. By the answers, one vessel- and one wind farm operator mentions fixed or jack up accommodation units on site and to operate these in combination with to a larger CTV. Ribs are also highlighted by three informants as a possible service that could be used on conjunction with either fixed platforms or a larger surface vessel.

All informants mention the larger surface vessel with a heave compensated gangway that could cover the operations in larger wave heights. The standpoint in operation of this vessel is to be stationary infield hosting 30-45 technicians on-board. This concept could in addition be equipped with daughter crafts, ribs or small CTVs for a more efficient distribution of technicians between different turbines.

Helicopters are mentioned by all as a solution for fast response and distribution of technicians and all agree that there will be more utilization in remote offshore wind farms with different options. The classification society mentions this concept to cover requirements of small repairs or services where limited amount of technicians and equipment is needed.

This can potentially be increased by having infield helicopters stationary on either vessels or on fixed platforms, this view was mentioned in three of the interviews. The benefits can be insignificant transfer time and even the transfer cost can be reduced making it worthwhile.

The potential of the CTV is also mentioned by all however the answers varies. The classification society believes that still the majority of all O&M task will be covered by CTVs. According to the vessel owners and also the classification society, larger and more powerful CTV's with additional passenger capacity will be required. An improved usability can be achieved by small improvements, like better fenders, the use of small personal transfer systems and a higher degree of flexibility i.e. being able to carry more cargo together with passengers are highlighted as possible changes that could increase the operability of the CTV. Despite that the respondents also address the limitations of operability and time efficiency with these concepts related to technician distribution as a difficult challenge. According to one wind farm operator *"If you have a vessel based accommodation concept, you still need to have flexible access possibilities and that a big challenge".* (Interview C, 2014-10-23)

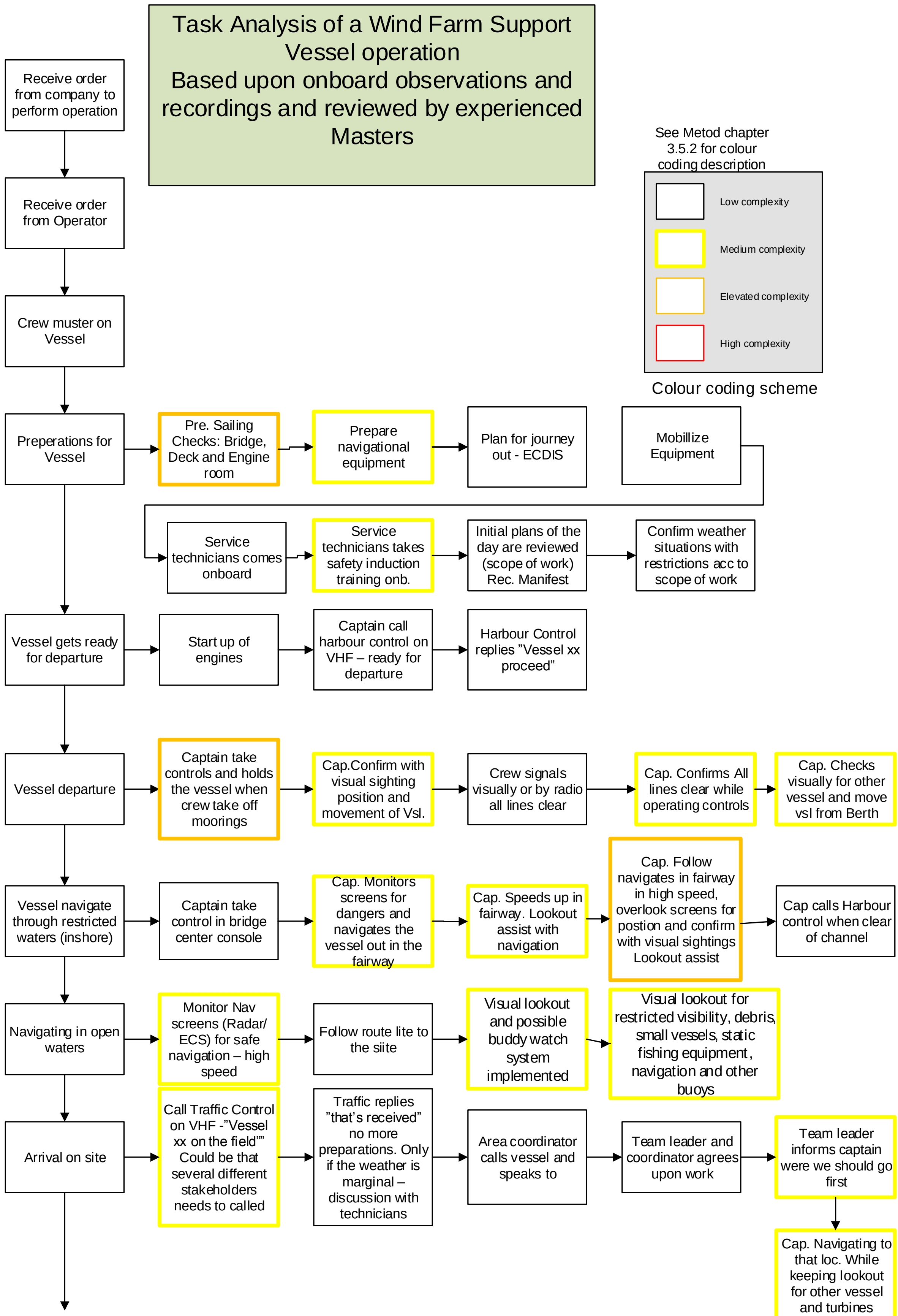
There exists a need to adjust technology with accessibility to meet the requirements that support safe and efficient transfer and this is a concern among several of the interviews. One of the vessel operators mentioned that. Experiences today with these types of solutions varies and some are not time efficient. A further development of this concepts is needed.

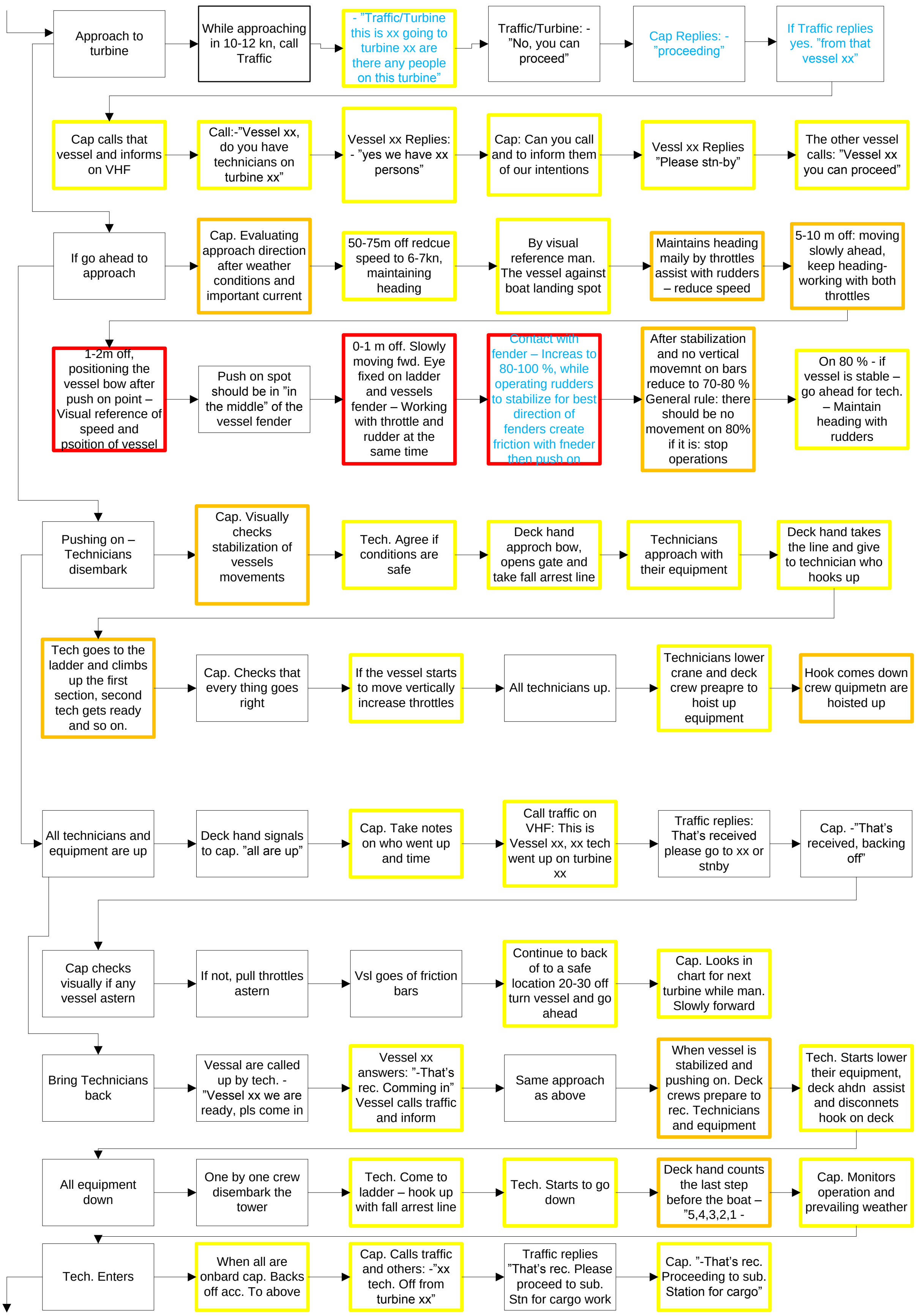
Regarding the mother-ship solution were the vessel can launch and recover smaller service vessels which could add a high degree of flexibility in distributing technicians teams faster across the field. The concerns among the informants refers to the launch and recovery systems, the construction and design of these need to be investigated and developed further due to the weather limitation for different launch and recovery systems and service vessel used. According to Interview A(2013-10-14); *Conditions more than 1,5 m makes it more difficult, even with mother-ships when it comes to the point where you should bring the vessel "home".*

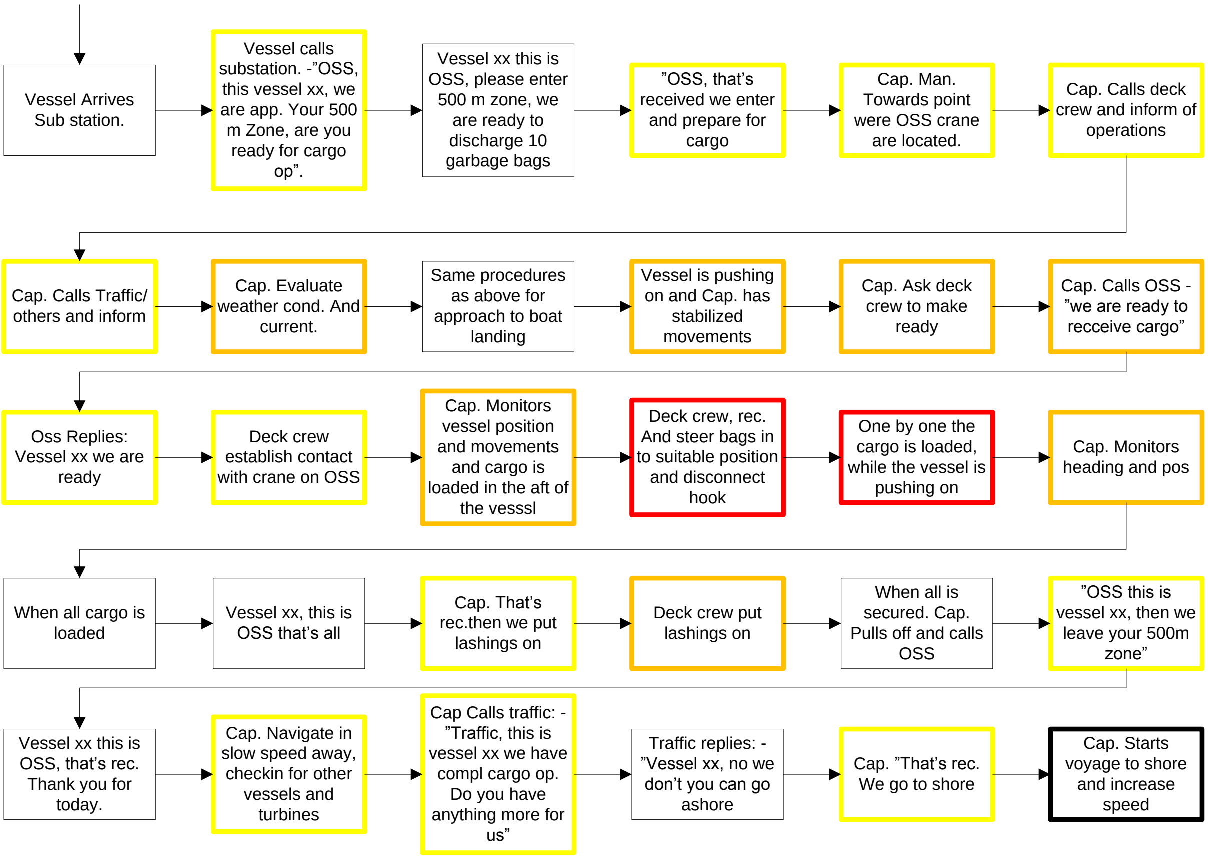
The increased safety focus in the industry is mentioned in two interviews which could have affection on the operations in far offshore wind farms. The ambition is to introduce more robust limits on safe transfer and to establish some clear rules and procedures around it. There exist a necessity to implement best practice guidelines and common approaches that different stakeholders can adapt to, which can provide better accessibility. Two informants also highlighted the work around the G9 group as vital for increased HSE involvements, where better abilities to perform incident reporting, can increase experience based learning across the industry from incidents and implement new corrective actions to increase safety perspectives within the industry.

4.2 Findings from Observations and Task Analysis

The hierarchical task analysis (HTA) in this report is a result of the observations, recordings and interviews during the CTV's operations in the wind farm.


Task Analysis of a Wind Farm Support Vessel operation
Based upon onboard observations and recordings and reviewed by experienced Masters
See Metod chapter 3.5.2 for colour coding description
Low complexity
Medium complexity
Elevated complexity
High complexity
Colour coding scheme
Receive order from company to perform operation
Receive order from Operator
Crew muster on Vessel
Preperations for Vessel
Pre. Sailing Checks: Bridge, Deck and Engine room
Prepare navigational equipment
Plan for journey out - ECDIS
Mobillize Equipment
Service technicians comes onboard
Service technicians takes safety induction training onb.
Initial plans of the day are reviewed (scope of work) Rec. Manifest
Confirm weather situations with restrictions acc to scope of work
Vessel gets ready for departure
Start up of engines
Captain call harbour control on VHF – ready for departure
Harbour Control replies ”Vessel xx proceed”
Vessel departure
Captain take controls and holds the vessel when crew take off moorings
Cap.Confirm with visual sighting position and movement of Vsl.
Crew signals visually or by radio all lines clear
Cap. Confirms All lines clear while operating controls
Cap. Checks visually for other vessel and move vsl from Berth
Vessel navigate through restricted waters (inshore)
Captain take control in bridge center console
Cap. Monitors screens for dangers and navigates the vessel out in the fairway
Cap. Speeds up in fairway. Lookout assist with navigation
Cap. Follow navigates in fairway in high speed, overlook screens for postion and confirm with visual sightings Lookout assist
Cap calls Harbour control when clear of channel
Navigating in open waters
Monitor Nav screens (Radar/ ECS) for safe navigation – high speed
Follow route lite to the siite
Visual lookout and possible buddy watch system implemented
Visual lookout for restricted visibility, debris, small vessels, static fishing equipment, navigation and other buoys
Arrival on site
Call Traffic Control on VHF -”Vessel xx on the field”” Could be that several different stakeholders needs to called
Traffic replies ”that’s received” no more preparations. Only if the weather is marginal – discussion with technicians
Area coordinator calls vessel and speaks to
Team leader and coordinator agrees upon work
Team leader informs captain were we should go first
Cap. Navigating to that loc. While keeping lookout for other vessel and turbines


Approach to turbine
While approaching in 10-12 kn, call Traffic
- "Traffic/Turbine this is xx going to turbine xx are there any people on this turbine"
Traffic/Turbine: - "No, you can proceed"
Cap Replies: - "proceeding"
If Traffic replies yes. "from that vessel xx"
Cap calls that vessel and informs on VHF
Call:-"Vessel xx, do you have technicians on turbine xx"
Vessel xx Replies: - "yes we have xx persons"
Cap: Can you call and to inform them of our intentions
Vessl xx Replies "Please stn-by"
The other vessel calls: "Vessel xx you can proceed"
If go ahead to approach
Cap. Evaluating approach direction after weather conditions and important current
50-75m off redcue speed to 6-7kn, maintaining heading
By visual reference man. The vessel against boat landing spot
Maintains heading maily by throttles assist with rudders – reduce speed
5-10 m off: moving slowly ahead, keep heading-working with both throttles
1-2m off, positioning the vessel bow after push on point – Visual reference of speed and psoition of vessel
Push on spot should be in "in the middle" of the vessel fender
0-1 m off. Slowly moving fwd. Eye fixed on ladder and vessels fender – Working with throttle and rudder at the same time
Contact with fender – Increas to 80-100 %, while operating rudders to stabilize for best direction of fenders create friction with fneder then push on
After stabilization and no vertical movemnt on bars reduce to 70-80 % General rule: there should be no movement on 80% if it is: stop operations
On 80 % - if vessel is stable – go ahead for tech. – Maintain heading with rudders
Pushing on – Technicians disembark
Cap. Visually checks stabilization of vessels movements
Tech. Agree if conditions are safe
Deck hand approch bow, opens gate and take fall arrest line
Technicians approach with their equipment
Deck hand takes the line and give to technician who hooks up
Tech goes to the ladder and climbs up the first section, second tech gets ready and so on.
Cap. Checks that every thing goes right
If the vessel starts to move vertically increase throttles
All technicians up.
Technicians lower crane and deck crew preapre to hoist up equipment
Hook comes down crew quipmetn are hoisted up
All technicians and equipment are up
Deck hand signals to cap. "all are up"
Cap. Take notes on who went up and time
Call traffic on VHF: This is Vessel xx, xx tech went up on turbine xx
Traffic replies: That's received please go to xx or stnby
Cap. -"That's received, backing off"
Cap checks visually if any vessel astern
If not, pull throttles astern
Vsl goes of friction bars
Continue to back of to a safe location 20-30 off turn vessel and go ahead
Cap. Looks in chart for next turbine while man. Slowly forward
Bring Technicians back
Vessal are called up by tech. - "Vessel xx we are ready, pls come in
Vessel xx answers: "-That's rec. Comming in" Vessel calls traffic and inform
Same approach as above
When vessel is stabilized and pushing on. Deck crews prepare to rec. Technicians and equipment
Tech. Starts lower their equipment, deck ahdn assist and disconnets hook on deck
All equipment down
One by one crew disembark the tower
Tech. Come to ladder – hook up with fall arrest line
Tech. Starts to go down
Deck hand counts the last step before the boat – "5,4,3,2,1 -
Cap. Monitors operation and prevailing weather
Tech. Enters
When all are onbard cap. Backs off acc. To above
Cap. Calls traffic and others: -"xx tech. Off from turbine xx"
Traffic replies "That's rec. Please proceed to sub. Stn for cargo work
Cap. "-That's rec. Proceeding to sub. Station for cargo"


Vessel Arrives Sub station.
Vessel calls substation. -"OSS, this vessel xx, we are app. Your 500 m Zone, are you ready for cargo op".
Vessel xx this is OSS, please enter 500 m zone, we are ready to discharge 10 garbage bags
"OSS, that's received we enter and prepare for cargo
Cap. Man. Towards point were OSS crane are located.
Cap. Calls deck crew and inform of operations
Cap. Calls Traffic/ others and inform
Cap. Evaluate weather cond. And current.
Same procedures as above for approach to boat landing
Vessel is pushing on and Cap. has stabilized movements
Cap. Ask deck crew to make ready
Cap. Calls OSS - "we are ready to recceive cargo"
Oss Replies: Vessel xx we are ready
Deck crew establish contact with crane on OSS
Cap. Monitors vessel position and movements and cargo is loaded in the aft of the vesssl
Deck crew, rec. And steer bags in to suitable position and disconnect hook
One by one the cargo is loaded, while the vessel is pushing on
Cap. Monitors heading and pos
When all cargo is loaded
Vessel xx, this is OSS that's all
Cap. That's rec.then we put lashings on
Deck crew put lashings on
When all is secured. Cap. Pulls off and calls OSS
"OSS this is vessel xx, then we leave your 500m zone"
Vessel xx this is OSS, that's rec. Thank you for today.
Cap. Navigate in slow speed away, checkin for other vessels and turbines
Cap Calls traffic: - "Traffic, this is vessel xx we have compl cargo op. Do you have anything more for us"
Traffic replies: - "Vessel xx, no we don't you can go ashore
Cap. "That's rec. We go to shore
Cap. Starts voyage to shore and increase speed

5 DISCUSSION

5.1 Operational limitations for crew transfer vessels

According to the result from interviews and seen in the HTA the major impact on crew transfer limitations is the wave height or factors arising from environmental conditions, like for example current and ice.
According to the interview investigation the main industry standard is 1,5m Hs, the conditions during the observations were Hs 1.5-1.7 m but declining. The HTA demonstrated different levels of complexity and revealed a higher complexity and increased workload for the crew during the access situations and the cargo operation. This indicates that these operations are critical in reviewing the tasks of the CTVs during those weather conditions.
Demonstrated by both methods from different perspectives strengthens that these limits could be an operational limit for CTVs, achievable for most vessels. The interview investigation revealed a value of 2.0m Hs as an upper and maximum limit the but then factors such as fender quality, vessel size and design, human performance, training and experience and power settings will have large impact in how to reach this limit. This hasn't been verified as part of this thesis but the indication remains that this may be achievable with a well-developed CTV and a competent and experience crew. According to Salzman (2007), this study on CTV performance confirms these values to some point and even if the vessels are being built stating a workability up to Hs 2.0 m, the windfarm operators claim a more adjusted level between 1,5-2,0 m Hs.
Another influencing factor is the current which was highlighted by the informants and the masters. Some fields have a very strong current and that could even have a larger impact then waves, if the boat landing design on the turbine has a direction that is not adjusted for the current.

In defining an upper critical limit for CTVs could be a difficult task for the industry especially when considering the recent incidents reports produced by the G9 group.
The first one is the annual incident report for 2013, which highlights "unclassed vessels" activity as part of marine operations, containing the highest numbers of incidents of around 70 of the total 131 (Energy Institute, 2014, p 24-25). What is classified as unclassed vessels? The author assumes that these can be connected to smaller CTV's where little requirements exist of classification. For the annual incident report of 2014 the number of incidents for marine operations have increased (the reasons can be that the reporting procedures are new and not fully communicated across the industry for the year of 2013). Here unclassed vessels have been replaced by vessels "less than 24 m". Of the 159 incidents that occurred on vessels, 44% were linked to crew transfer (Energy Institute (G9), 2015).
The connectivity between vessels incidents and critical transfer limits hasn't been verified but small vessels or unclassed are associated with the highest risk in marine operations and especially connected to crew transfer. Access to turbines is one of the biggest safety issues. It should not only be viewed from the capabilities of different CTV designs, other factors such as human factors and human performance play a key role in achieving that.
It should be mentioned that industry organizations such as the G9 group, IMCA and also Renewable UK have now produced different HSE guidelines and industry practices for these operations. The ambition is to get a more uniformed standard and a better HSE perspective across the industry and the informants highlights this perspective as need for the industry to develop further.

Another perspective that could have affection on upper limitation for crew transfer is training and experience of technicians for offshore activities. According one windfarm operator, their experience is 1,2m Hs as a limit where the technicians feel more comfortable in. However this wasn't confirmed by other interviews.
The Renewable UK (2013) addresses skills and experience of crew(s) as a factors to consider in access situation, despite that it doesn't address what to consider if the crew is unexperienced. A good standpoint how to work commonly to increase the awareness in crew transfer is as one of the vessel operators mentions; *If you got well-designed vessels which reduce vertical movement and you will increase the transfer height, if you got an experienced Captain/crew and the technicians got confidence in everybody on-bard you have got a good setup, not by pushing the boundaries but got better confidence in transferring in larger wave heights.*

The other main factor influencing vessel limitations is the transfer distance and the capability of the CTV to uphold a high speed in relation rougher sea conditions; here technological improvements in vessel design like SWATH have increased the boundaries in operating in higher sea heights with an acceptable comfort.
The result mentions the smaller CTV's transfer limit of 15-20NM from shore. Exceeding that limit to 30 NM the transfer time becomes critical for these vessels as time on site for different duties will be reduced. In addition 50 NM is also mentioned as a limit for larger CTVs operating from shore based approach. In these conditions the distance will have a large affection on O&M costs, due to the amount of fuel used. This corresponds with data coming from Bard & Thalemann (2011) in verifying transfer limits from different types of CTV's. The study used input from the windfarm operators where they defined an acceptable transfer time of 60 minutes and 80 minutes as maximum.

The data that were produced (see section 2.3.3.1) revealed that the maximum transfer time created a maximum deployment distance of 23 NM for SWATH CTV's, 28 NM for Catamaran CTVs and 40 NM for monohull CTVs. (It should be noted that these numbers haven't been confirmed with different vessel manufactures) However, based upon that data a proposed wind farm working area of 50 NM offshore, no CTV could arrive at site on time as it will reduce the working time for technicians significantly (Bard & Thalemann, 2011). This strongly indicates that the transfer distance is crucial and even becomes critical when distances go beyond 40 NM. Adding marginal weather conditions then this limit might be reduced more.

5.2 Current access system and procedures

As mentioned above the two main factors that affect vessel limitation are sea heights and transfer distance from port. The most common access method today for CTV's are "bump to bump" the CTV pushes on the boat landings with forward propulsion and by that stabilizes the motions in all degrees of freedom. The HTA demonstrates this procedure and also identifies the parts with the high complexity or increased workload for the crew. The final approach and the push on sequence and in higher sea states, this may become more critical. The rule of thumb as mentioned in the interview and also by the masters: *"if the vessel moves 2 runs on 80 % we cannot move on 100% and if it's an increase of forecast, we can get to the point that we put the passengers up and we know that we move 2 runs at 80 % and if the forecasts is increasing we may end up to 100 % and moving still.*

Procedures for access or crew transfer from organisations like IMCA, G9 and the Renewable UK provide best practice guidelines for these types of vessels. They do not mention specific wave heights, but they indicate that potential wave heights can vary from location to location. In addition they mention that all risks should be identified and the maximum wave height can be increased by the use of transfer access systems and active fenders (IMCA, 2014)
The Renewable UK's *safety guidance for offshore renewables energy developers* (2012) mentions:

- *"The selected vessel must be capable of operations within the expected prevalent conditions with a safety margin to allow for changes in environmental conditions;*
- *A common understanding of the limitations of the vessel between all parties is essential;*
- *The environmental conditions should be below the limits set within the risk assessment and procedures for the activity."*

This doesn't address any specific wave heights but connect the vessel capabilities to present environmental conditions which should be seen as a more balanced level of vessel limitations. There are procedures in place up to 1,5m significant wave height (Hs) which many operators has as an industry standard, however as operations do occur in wave height above that, these have no clear stated procedures. IMCA addresses use of transfer access system as a possibility to operate in larger wave heights. According to Marsh (2013) many of these transfer access options can work in wave heights of 2,5m which is also mentioned by Knudsen *et al*. (2011). Marsh (2013) address the challenge in finding solutions that could work in higher sea states; there are two schools of thought in which ways this can be met.

- Active positioning
- Passive positioning

The result from the interview investigation addresses these most associated with larger vessels and the use of a "walk to work" solution (Active positioning). This type of gangway from the vessel to the turbine could according to the interviews also work in higher seas states. At the same time all interviews questioned the efficiency in this solution, due to the set-up time for conducting transfer, especially if the field is large, this may be a time consuming task.

5.3 Changing operational requirements in remote offshore wind farms

The focus to develop windfarms further offshore will be affected by increased environmental conditions and increased transfer time and the operations will become more difficult to handle with regards to safety and efficiency. According to the interview investigation this will require a different logistical model and strategy to achieve the tasks in the O&M phase.
From a windfarm operator perspective they have an ambition of a 95 % availability for best cost efficiency. That is also mentioned by GL Garrad Hassan (2013) in an ambition to achieve the theoretical point of least cost, the availability needs to be between 90-95%.

Scheue *et al.* (2012) addresses this with respect of financial risk for potential investors and in order to found large scale offshore wind farms. The wind turbine availability is the main influencing factor as this determine the obtainable income factor direct. O´Connor (2012) addresses the importance of fast on repairs and device recovery as a necessity to ensure high availability. This can be summarized in: that high availability is necessary in remote offshore wind farms. A required level of availability is dependent on an acceptable level of accessibility.

In the literature, the issue of accessibility is determined by the percentage on how frequently that turbine can be accessed during different conditions; this is a major factor that will affect the operation of an offshore windfarm (Salzman et al, 2009). The access problem can be highlighted in the effect of device availability; availability is defined by the amount of time the turbine is operational to create electricity (Faulstich et el, 2009). In a statement from the interviews; "*With current access methods there would be around 200 days access (at 1.5m Hs limit) for UK Round 3 sites* (Remote offshore, authors note). *Most existing sites aim for around 300 days access, so a drop to 200 in Round 3 would simply not be practical in the sense of number of days a year that the site can be accessed by vessels.*
UK round 3 sites which includes Dogger Bank but also some of the bigger sites near shore, you can't keep a farm operational with that level of accessibility". (Interview F, 2015-04-15)

This highlights that a level of 1, 5 Hs is not sufficient when going further offshore, like the planned UK round 3 sites and some farms already in operation in the German sector.
Both Van Bussel & Bierbooms (2003) and Salzman (2007) highlight this challenge and demonstrate in their studies that an increased accessibility will require transfer in higher wave heights. Especially Salzman provided interesting data for a factious wind farm 54 NM off the coast. If an acceptable level of availability require an accessibility of 87 % (317 days/year) that will require operations in 2,5m Hs (page 8). For the same farm, 1.5 Hs demonstrates an accessibility of 60 %, which is 219 days/year. In both conditions the data produced corresponds roughly with data in the statement from interview F above. This indicates that a remote offshore wind farm will require operations in levels of 2-2.5m Hs in maintaining an acceptable accessibility. However it should be noted that different farms have different local characteristics and different sea areas also have different characteristic, the values should not be generalised but the indication remains.

Cost is another challenge which was addressed as a main challenge for the whole offshore wind industry, the interviews highlight the transfer of experience and knowledge to new projects as vital in this respect for a stable development and cost utilization.
Fischer *et al.* (2013) mention a cost factor for O&M of 15-30%. Maintenance and support strategies are vital for cost efficiency. However in meeting a requirement of high accessibility in remote offshore, the cost will most likely increase but then the availability is remained high.

5.4 Development of access systems in remote offshore windfarms

Access system working in remote offshore windfarms will be more exposed to the environmental forces and could encounter sea heights of 2-2.5 m Hs. With regards to the answers in the result remote offshore windfarms will require another type of combined logistical model and by that another strategy in achieving a required accessibility.

The main result of the interview investigation addressed the SOV with a gangway and an additional function to launch and recover smaller CTVs for a more efficient technician distribution as an additional option. The CTVs could operate in less wave height and the gangway solution in a more elevated wave height. Previous research also addresses this concept were Fisher *et al* (2013) modelled different concepts for an offshore wind farm of 100 turbines and 60 km from shore(32 NM). The study came to the conclusion that an offshore accommodation on service 24h/7 and a crew transfer vessel with a heave compensated transfer system were most appropriate. The interviews also address helicopters as an additional solution.

Their operability could add an increased accessibility especially if they are stationed offshore on either vessels/SOV or on another type of fixed platform, like a substation. The importance for remote offshore windfarms is to involve or combine different available transfer concepts during the O&M phase.
The results from interviews also demonstrate that the role of the CTV will not change, the main task will still be crew transfer however; small adjustment in for example fender quality, power capabilities and design can increase wave height boarding to some extent. However the issue of human performance or the impact of human factors; i.e. being able to cope with rougher conditions and in critical operations, the impact of motion sickness and training and experience have large impact on meeting higher demands while operating in rougher environmental conditions.

The upper limits for the crew transfer vessel is a difficult task to define, and that alone is an important definition to establish when the wind farms becomes more remote. The conditions during the observation for the HTA was 1.5-1.7 m Hs and declining, the vessel remained stable while pushing on in 80% power setting.
Knudsen C *et a*l (2011) demonstrated an upper transfer limit of 2.5m for the SWATH concept and between 2-3m Hs for vessels with motion compensated gangways. The study by Salzman (2007) provided an accessibility value of 90% for a wind farm 54 NM (see section2.1.3) of the coast of in 2.5m Hs. The upper limits mentioned in the interview investigation for CTVs were 2.0m Hs that would in the same wind farm provide an accessibility of 76%, and for the value of 1.5m Hs, an accessibility of 60%.
While adding the impact of transfer distance where Bard & Thalemann (2011) mentioned 80 minutes as a maximum of transfer time in their study and compared with the other data produced concerning different CTVs capacity no CTV could arrive in time for that farm 54 NM of the coast.

This can be summarized: in defining the upper limits of CTV capability adds one value with and without different solutions of motion compensated gangways. In defining a limit of operability of a specific CTV the discussions demonstrate that factors such as technicians' experience, transfer time, power setting, human factors and HSE perspectives provide a lesser value. For example the incident statistics alone demonstrates necessity of established HSE procedures and guidelines in defining better operational criteria for crew transfer. This section highlights the complexity in finding a logistical model and resources that could cover the duties for the O&M phase for a wind farm in for example 54 NM from the coast in maintaining acceptable level accessibility. The solution will most likely to be concentrated on a stationary accommodation concept on location of the farm.
These issues indicate that there exist gaps between technological, operational and human factors criteria in these types of operations. These need to be defined better and the solutions to overcome these could be to establish joint industry projects and cooperation like the work around the G9 group. These will have more importance in the future when the wind farms become more remote, to summon involved stakeholders and work commonly against new requirements and define clear HSE limits, guidelines and required procedures.

5.5 Methodological considerations

In 1985, Lincoln and Guba in their conversation on trustworthiness asked (p290)
"How can an inquirer persuade his or her audiences (including self) that the research findings of an inquiry are worth paying attention to, worth taking account to?"
In response to this question, the choice of methods and data collection process is of importance. The main research in this thesis has been qualitative, often this approach has been seen as subjective compared to quantitative as more objective. Traditionally in natural science quantitative approaches have been used but in the area of civics there have often been a mix between quantitative and qualitative research approaches (Kvale, 1997). Kvale argues that these approaches are methods, and their use depends on the research questions used, as this thesis was explorative and with an ambition to create theories that defends to some extent the choice of a qualitative approach.

The mixed method approach motivates the selection of methods used in this thesis, as the semi-structured interviews alone cannot provide a sufficient data for the result. When combining this with the HTA a more complete and validated result can be provided.
In selection of method(s) for this thesis, initially the primary research method was semi-structured interviews. When it later arose an opportunity for an on-board observation in a remote offshore wind farm, it became obvious that the result from the HTA would have an impact on the outcome from the interviews and the combination of these would provide a more complete result.
It has also been a great personal learning process to carry out a mixed methodology approach focusing on interviews and the HTA through the on-board observation.

5.5.1 Written sources

As the thesis also focus on different vessel types, access system concepts and procedures other written sources were needed. The information from these areas mainly comes from relevant industry organisations, classification societies and also direct from different providers such as vessel and access systems manufactures.
The data coming from different industry organisations and classification societies are to be seen as relevant as much of the content in these reports are developed by a team of professionals, and are regarded reliable and trustworthy with regards to facts and findings.

5.5.2 Interviews

In the beginning of the thesis the ambition was to use only interviews as a qualitative method. The intention was then to incorporate additional informants from vessel- and transfer system manufactures as their contribution could have provided interesting information on vessel capabilities with regards to CTVs and also for different transfer system. That input might have added some further consideration making more absolute answers to limitation of vessels and different access systems in the result section.

Five industry representatives were selected due to the possibility to conduct the on-board observation. The reliability of the informants is considered to be high as they represent different perspectives and responsibilities within the industry. This is important to the extent that qualitative research result can be generalised as different opinions are provided from different perspectives (Denscombe, 1998) In qualitative research the interview as a method has sometimes been seen as a method that is not scientific and lacking from objectivity (Kvale, 1997).

However as this thesis focus on practical or operational parameters, practical experiences and knowledge are in focus Kvale argues that qualitative interviews are more legitimate as the result will more focus on to contribute to changes in these areas (Kvale, 1997).

Conducting interviews has been a challenge, although the key of being well prepared is crucial, sometimes it doesn’t help due to lack of experience in how to conduct the interviews. Another factor might be the personal experience that the author has from other types of offshore operations, that might have affected the way the interviews were conducted, since it was difficult not be biased. However that weakness could also be used as an advantage in knowing the offshore area, a better connection to the respondents could be established and be used to get more insight to the subject.
If structured interviews had been used the personal experience would have been reduced but then there would have been a risk that deeper knowledge and explorative data would have been lost.

5.5.3 On-board observation and HTA

Due to the fact that the wind farm was classified as remote and weather was marginal, it became vital both for the author to experience these conditions and type of vessels but also for the validity of the thesis, as the intention was to focus on remote offshore wind farms.

5.5.3.1 Why observe under Naturalistic conditions

- Participant observation has better prerequisites to incorporate the operational environment then other methods
- This approach gives better possibilities to gain insight in different processes that is going on in the observed environment
- Studies that build on this type of observation allow holistic explanations which concerns connection between many different factors
- It provides an opportunity to “step in to the eyes” of the involved personal and by that experience decisions and assumption made during different activities

(Descombe, 2009)

5.5.3.2 Constraints under Naturalistic conditions

- The researcher has limited options in which roles he or she can be in and what type of environments he or she can be a part of
- This type of observation comes with risks which have to be evaluated before the observation is initiated
- The credibility of the data can be questioned as these data are not verified by other sources, the objectivity of the observer is of outmost importance
- Are the conditions representative for its nature? Could other conditions give another type of data and these views can provide difficulties in generalising the result

Descombe (2009)

A hierarchical task analysis was chosen since it was expected to give timely results, and would not interfere with the operation. There is an intrinsic limitation with this method: cognitive processes and the level of mental workload needed in each step of the process are not direct part of the analysis.

With regards to complexity, that level was quantified in the view point of the author which can be seen as a weakness in this method, as it is based upon subjective assumption of what task is to be graded more complex than another.
As there were no possibilities to verify the workload at the time of the observation, the author decided to use his own experience from other type offshore activities involving vessel operation as a standpoint in this analysis. However in verifying the assumptions made, the HTA has in addition been reviewed by the involved master and also by another master working on a similar vessel but for another company that increase reliability of the HTA.
The HTA is also a very flexible and can be used in many different domains. Of course the method has some disadvantages, the person conducting the method has to know other methods used in the data collection such as interviews and observations. The method also mainly consists of only descriptive information rather than analytical information and some other method needs be conducted to get that kind of information (Stanton *et al*. 2006)

5.5.4 Cross-reference HTA and Interviews

The main challenge on the other hand has been to cross-reference data from the interviews and the HTA together in a constructive and analytic way that it would add relevance and reliability to the answers of the research questions. There exist difficulties in trying to answer some of these in reviewing the content of the HTA only; the best contribution is providing answers to procedures of personnel transfer. These answers were also verified in the interviews. Secondly the the interviews doesn't address the complexity and human performance in this operation, which is important in the analysis to understand in making the right assumptions while defining limitations. In reviewing the outcome from the interviews they add a more overall picture and incorporating other importance factors such as technological and operational. .
With this combined perspective and width there exists a better foundation in making grounded assumptions in providing answers regarding operational constraint for CTV's in remote offshore wind farms.

5.6 Future Research

One further research area could be to involve a stronger human factor's perspective. Human factors have a well-recognized impact on marine operations. In these operations issues like seasickness, motion induced performance and fatigue have affections on the performance of crews and technicians. This needs to be explored better and especially if the ambitions is to identify the gaps between technical, operational and human factors. This could provide further insights in how these operation can be developed.

Another area worth focusing more on is the high number of incidents in marine operation which is mentioned in the thesis. Doing a more thorough analysis into the root causes could also provide interesting result that could be useful in developing the HSE frameworks and procedures involving these operations.

6 CONCLUSIONS

The necessity of high availability in remote offshore wind farms is crucial for the development and also in defending that ambition to be attractive in the future from many perspectives like; the impact on electricity price, political and public support and even to attract investors. The level of availability is dependent of an acceptable accessibility. Remote offshore wind farms will require that the operational margins for crew transfer need to be increased in maintaining that for the O&M phase.

The limitations of the CTV's can to some extent cover operational requirements and still remain safe and efficient, but an increased transfer time will limit that option.
There also exists a need within the industry to have a better verification of "operability" of vessels and definition of "capability" with regards to operation in higher sea state.
There should also be a distinction between these words as operability could be affected by other factors such experience from technicians and marine crew, procedures, human factors etc. The HTA highlights two areas that involved a higher complexity: cargo operations with CTV's and crew transfer in marginal weather. In a strive for further development in remote offshore windfarms, what can be done to reduce that complexity is one of the priorities in facing the challenges in going further offshore. Establishing procedures and methodologies to encounter that is most vital

The main result demonstrates that the SOV concept will meet the requirements in working in rougher sea conditions however its efficiency in technician distribution needs to be increased if it should remain a cost effective solution. Adding smaller CTVs on-board or by providing a helipad for the use of helicopters could improve this combination.
Still the industry is learning and fast project utilization reduces the ability to transfer knowledge and experiences into new projects. Therefore a more common approach through more standardization is necessary in the future to achieve a stable development in a more "remote" direction.
Safe operations are paramount in all offshore activities, hard learnings from the oil and gas segment like the accident involving the anchor-handler Burboun Dolphin, where lack of clear operational and safety limits allowed a tragic accident to occur.
Safe and efficient transfer of personnel in changing operational requirements in remote offshore windfarms was the focus of this thesis, it's indicated that this can not only be viewed from a few perspectives, but the importance is too establish clear safety boundaries and build a framework around.

Mentioned by many, cost seems to be the main challenge for the industry but the ambition of windfarms further offshore will increase the cost due to increased operational requirements. The importance is to be cost efficient and prioritize a balanced development but on the other hand, cutting corners in marine activities is seldom a wise decision as safety often becomes affected.

The outcome and development of the new Dogger Bank project located around 70 NM off the east coast of England highlight many challenges addressed in this thesis for the O&M phase. However it does also present a unique opportunity to have another approach in the design and planning phase involving different stakeholders in the O&M phase early, which according to this thesis could be a necessity for safe and efficient operation.

7 REFERENCES

Ampelmann (2015), *Ampelmann A-type,* http://www.ampelmann.nl/products/e-type/, (Retrived 2015-03-01)

Autobrow (2015), (http://www.autobrow.com/www.autobrow.com/Autobrow.html, (Retrieved 2015-03-22)

Bard J. & Thaleman F. (2011), *Offshore Infrastructure: Ports and Vessel*, Fraunhofer IWES, www.orecca.eu

Besnard et al (2013), *A model for the Optimization of the Maintenace Support Organisation for Offshore wind farms*, IEEE Transaction on Sustainable Energy, Vol 4, No 2

Bonafoux, J. (2011). *Getting Into Ship Shape For Far Offshore*. Wind Technology pp. 11-13.

Calqlata (2015), *Vessel motions in 6 degrees of freedom* http://www.calqlata.com/productpages/00059-help.html (Accessed 2015-05-19)

Carbon Thrust (2008) *Offshore wind power: big challenge, big opportunity Maximising the environmental, economic and security benefits*, https://www.carbontrust.com/media/42162/ctc743-offshore-wind-power.pdf (Retrived 2013-09-15)

Cohea, W. W. (1997). *Report on the Joint Industry Project on Human Factors in Offshore Operations*. Houston: EQE International Inc. Report available at http://www.boemre.gov/tarprojects/220.htm.

Costa Ros, M. & Mockler, S. (2013) *Carbon Trust Offshore Wind Accelerator - Driving down the cost of offshore wind*, Presentation London, 29 January 2013

Dai, L. (2014), *Safe and efficient operation and maintenance of offshore wind farms*, Doctoral thesis at NTNU, 2014:70, NTNU – Norwegian University of Science and Technology, Trondheim

Dahlén, G. & Jakobsson, M. (2009) - *Access to offshore windfarms*, ch 10 Offshore Wind Power by Twidell, J. & Gaudiosi, G. (2009)

Denscombe, M. (2009). *Forskningshandboken - för småskaliga forskningsprojekt inom samhällsvetenskaperna*. Lund: Studentlitteratur AB

DNV GL (2013), *Service on Windfarms and other Offshore Installations - RULES FOR CLASSIFICATION OF High Speed, Light Craft and Naval Surface Craft PART 6 CHAPTER 30*, Retrieved from DNV GL 2014-10-28 http://www.dnvgl.com,

Energy Institute (2014), *G9 Offshore wind health and safety association; Good practice guidelines – The Safe management of small service vessels used in the offshore wind industry*, Energy Institute, London www.energyinst.org

Energy Institute (2014), *G9 Offshore wind health and safety association; 2013 annual incident data report*, Energy Institute, London www.energyinst.org

Energy Institute (2015), *G9 Offshore wind health and safety association – 2014 incident data report*, Energy Institute, London www.energyinst.org

EWEA (2009), *Wind Energy – The Facts: A guide to technology*, Economics and future of Wind Power. Earthscan, London

EWEA (2011) *Wind in our Sails The coming of Europe's offshore wind energy industry* A report by the European Wind Energy Association – 2011, www.ewea.org

EWEA (2014), *Annul Report 2013,* (http://www.ewea.org/fileadmin/files/library/publications/reports/EWEA_Annual_Report_2013.pdf) Accessed 2015-05-05

EWEA (2014), *Wind energy scenarios for 2020,* http://www.ewea.org/fileadmin/files/library/publications/reports/EWEA-Wind-energy-scenarios-2020.pdf (Retrived 2015-05-05)

European Commision, 2006, *Renewable Energy Roadmap*, COM (2006) 848 final
Energy trends to 2030-2009, European Commission, 2010.
Faulstich S, Lyding P, Hahn B, Callies D (2009) *Offshore – WMEP: monitoring offshore wind in use*, In: European wind energy conference. Stockholm, http://www.eow2009.info/ (Retrived 2014-10-01)
Feng Y, Tavner P and Long H (2010), *Early experiences with UK round 1 offshore wind farms*, Proc. Inst Civil Eng., 163, p167-181
GL Garrard Hassan (2013), *A guide to UK offshore wind operations and maintenance*, Scottish Enterprise and the Crown Estate
Halvorsen-Weare Elin E et al (2013), *Vessel fleet analysis for maintenance operations at offshore wind farms*, Energy Procedia 35 (2013), 167-176, Elsevier Ltd
Hollnagel, E. (2006). Task Analysis: Why, What, and How. In G. Salvendy (Ed.), *Handbook of Human Factors and Ergonomics* (Vol. 3). Hoboken, NJ: John Wiley & Sons.
IMCA (2014), *Guidance on the Transfer of Personnel to and from Offshore Vessels and Structures*, IMCA SEL 025 Rev. 1, IMCA M 202 Rev. 1.
Jensen C (2004), *Access to offshore wind turbines, screening report*, Offshore Center Denmark DOC. NO. 4003srer1, Esbjerg
Knudsen C et al (2011), *HSE challenges related to offshore renewable energy*, SINTEF Technology and Society Report A18107, Trondheim
Kvale, S. (1997). *Den kvalitativa forskningsintervjun*. Lund: Studentlitteratur AB
Lincoln, Y & Guba, E. (1985), *Naturalistic inquiry*, Beverly Hills, CA, Sage.
MacAskill A and Mitchell P (2013), *Offshore wind – an overview*, WIREs Energy Environ 2013, 2: 374–383
MAIB (2013), *Accident Report – Windcat 9 and Island Panther*, Report No 23/2013 (Marine Accident Investigation Branch) https://www.gov.uk/government/organisations/marine-accident-investigation-branch
Marsh G (2013), *Deep offshore O&M: accessing all areas*, January/February 2013 | Renewable Energy Focus, p 24-30
The Maritime Executive, MarEx (2015), *World's Largest Offshore Wind Farm Approved*, http://www.maritime-executive.com/article/worlds-largest-offshore-wind-farm-approved, (Accessed 2015-02-17)
MaXccess by Osbit Power 2015, (http://www.osbitpower.com/technology/maxccess, (Retrived 2015-03-22)
MIL-STD-882D (2000), *Standard Practice for System Safety*, US Department of Defense, Washington, DC
MOTS 2015, (Momac Offshore Transfer System) (http://www.momac-robotics.de/MOTS-500-momac-Offshore-Acccess-System-for-crew-vessel-boat-landing.html, accessed 2015-03-22).
Platt, J (1981), *Evidance and proof in in documentary research*, The Sociological Review, 21(1): 31-66
Rademakers L, Braam H, (2002) – *O&M Aspects of a 500 MW offshore wind farm at NL7*. DOWEC-F1W2-LR-02-080/0. Petten, http://www.ecn.nl/fileadmin/ecn/units/wind/docs/dowec/10080_002pdf (Retrived 2014-10-15)
Renewable UK publication (2012), *Vessel Safety Guide Guidance for Offshore Renewable Energy Developers*, RenewableUK Standards and Accreditation www.renewableuk.com (Retrived 2014-10-19)
Renewable UK (2013), Offshore Wind and Marine Energy Health and Safety Guidelines 2013: Issue 1, SgurrEnergy Ltd (www.RenewableUK.com)

Renewable UK publication (2014), *Health & Safety Training Entry- and Basic-Level Health & Safety Training and Competence Standards: Scope and Application to Large Wind Projects (2014)*, Renewable UK Standards and Accreditation www.renewableuk.com (Retrived 2014-10-19)

Sharples M, Sharples BJM. (2010) *Damage and critical analysis of accidents to assist in avoiding accidents on offshore wind farms on the OCS.* Tech. rep. Offshore: Risk & Technology Consulting Inc.

Stanton, N. A., Salmon, P. M., Walker, G. H., Baber, C., & Jenkins, D. P. (2006). *Human Factors Methods: A Practical Guide for Engineering And Design*: Ashgate Publishing Company.

Salzman DJCvdT J, Gerner FWB, Gobel AJ, Koch JML. (2007) - *Ampelman demonstrator – developing a motion compensating platform for offshore access*. Berlin: European offshore wind, http://www.eow2007.info/index.php?id=16 (Retrived 2014-10-01)

Salzman DJCvdT J, Gerner FWB, Gobel AJ, Koch JML. (2009) *Ampelman – the new offshore access system*. In: European wind energy conference. Stockholm, http://www.eow2009.info/

Scott, J (1990) *A Matter of record*, Cambridge: Polity Press

TAS (BMT & Houlder Turbine Access Systems), 2014. (http://www.bmtng.com/design-portfolio/turbine-access-system/, accessed 2015-03-22). TAS, 2015 http://houlderltd.com/case-study/tas-turbine-access-system/ (Retrived 2015-05-09)

Uptime (2015), *SOV "Walk to work"*, http://www.uptime.no/?p=948 (Accessed 2015-05-19)

Van Bussel G & Bierbooms W (2003) – *Analysis of different means of transport in the operation and maintenace strategy for the reference DOWEC offshore wind farm*: Proc OW EMES; 2003. Naples

Van Bussel G (2002) – *Offshore wind energy, the realiability dilema.* http://www.lr.tudelft.nl/fileadmin/Faculteit/LR/Organisatie/Afdelingen_en_Leerstoelen/Afdeling_AEWE/Wind_Energy/Research/Publications/Publications_2002/doc/Bussel_Offshore_wind_energy.pdf (Retrived 2015-02-10)

Wikipedia (2015), *SWATH design* http://en.wikipedia.org/wiki/Small-waterplane-area_twin_hull#/media/File:SWATH_waterline.svg (Retrived 2015-05-05)

Zander, E. (2009). *Designing A Wind Farm.* (EWEA, Ed.) Wind Directions , 28 (5), p. 52.

APPENDIX A

Interview Questions for Master Thesis

Semi-structured Way

General introductive questions

1. We see a quite big development in wind offshore industry today, the outlooks if you follow EWEA's prognosis is positive and will continue to be so, what do you see as the main challenges for the wind offshore industry in the future?

Present Situation

2. Much concerning the O&M operations today is affected by a "safe access" situation for the wind farm support vessels, what do you consider to be the operational challenges that affect a safe and efficient access to wind turbines?
3. You as a classification society how do you handle these issues with regards to safe access, what demands are relevant from your perspective?
4. Concerning access systems (vessel and access method), do you believe the solutions that exist today are good?
5. What do see as the main criteria's that affect vessel limitations?

The future and remote offshore wind farms

6. How will remote offshore wind farms affect the operational limitations for O&M?
7. With increased focus on higher accessibility in the future from the wind farm operators, what can be done to meet this?
8. How can the present access system and procedures be developed in order to meet these new demands? Is higher accessibility achievable for wind farm support vessels?

APPENDIX B

Interview question as a part of Onboard Study offshore

Questions for marine crew

- Give a short description of a normal day at work – What is your duties during the operation?
- What is the most challenging part?
- For a boarding/access situation how do plan for that, procedures?
- How would define accessibility?
- What will describe a boarding situation during normal conditions, with regards to external conditions?
- What is a more extreme condition of boarding?
- Are the procedures in place today to conduct boarding in higher wave heights such as 2,0m Hs and above? – Is it achievable with regards to an acceptable safety level?
- What would you think of as solutions/procedures to conduct boarding in higher sea levels?

HMI (human machine interface)

- Does the bridge layout with screens, handles, and ergonomics support the various task you are conducting?
- Is the information presented easy readable and supportive?
- What is your opinion about ergonomics and seating arrangements, good overview?
- Do you have any decision support tools that you know of in your bridge equipment?

Training

- What is your previous experience?
- Are the relevant training standards in place to meet the demands from offshore wind industry?
- Is there a need for other type of training?

Technical interviews for Dantysk

- Give me a short brief of a normal day at work
- How do you consider a good technical availability?
- What do you consider as an acceptable maintainability?
- How does your personal safety equipment affect your technical tasks?
- How does the environmental ambient conditions affect your technical tasks?
- Give a short brief of the risk assessment procedure?
- What kind of maintenance plan/system involves your tasks?

APPENDIX C

Collaborative project co-funded by the European Commission in the Leonardo da Vinci Lifelong Learning Programme

EBDIG Wind Farm Support Vessels Stakeholder Interviews

- Participant Consent Form

EBDIG-WFSV (European Boat Design Innovation Group - Wind Farm Support Vessels) is a Leonardo TOI (Transfer of Innovation) project that has created innovative learning materials for Naval Architects and Project Managers working within the Wind Farm industry and a networking framework. By transferring embedded practices within the leisure marine and automotive industry through courses in: Human Systems Integration; WFSV Design; WFSV mothership design . Delivered by an interactive web based Digital Innovation Studio (DIS). The learning materials includes presentations, CAD images and CAD training videos. The courses are available through the project website www.ebdig.eu by the use of a password available by registering on the website.

Recent research has indicated that current wind farm support vessels will not be appropriate for accessing far shore wind farms. In order to improve operability of WFSV accessing the far shore wind farms, mothership vessels will be required. Interior design principles applied to vessel accommodation will help to reduce the adverse effects of shift work, through creating a low stress appealing living environment. Human Factor Integration (well established in the defence sector) in the design of the bridge will reduces cognitive workload and hence reduce the risk of human error, the most significant cause of marine accidents.

We are currently collecting information about the factors affecting on board work and performance on existing wind farm support vessels and similar environments board in order to inform stakeholders. We will then identify factors which can be addressed by the design process and introduce these through the project website.

Your participation is voluntary and you have the right to withdraw at any time without having to give any explanation, in this case your data will be deleted. We certify to treat collected data according to good practice and follow sound ethical rules. Responsible for personal data is Chalmers University of Technology.

No personal data will be collected or recorded except: type of work performed, years experience.

If you have any questions or comments concerning this study you can ask the project personnel on site or contact the person responsible for the study:

Name: Christopher Anderberg
Address: Chalmers University of Technology, Department of Shipping and Marine Technology, SE-412 46 Gothenburg
Phone: 031-772 26 21, Email: christopher.anderberg@chalmers.se

I hereby give my consent that sound recordings are made during the study and stored. I understand that the information contained in these may be used in presentations and project publications, including project website and portal. I agree on the described usage of the voice recordings without restriction in terms of time or location.

Signature: ______________________ Date: ____________

Name (block letters): ______________________