

A Job Task Analysis for Technicians in the Offshore Wind

Industry

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Abstract

BACKGROUND: To establish whether an organization has a valid Physical Employment Standard (PES), it is important to determine those aspects of the job that are critical to operational success.

OBJECTIVE: To determine the tasks of the Offshore Wind Industry (OWI) and whether the ability to undertake these tasks is adequately assessed. **METHODS:** The task analysis was completed through: observations; the research team undertaking tasks; reviewing operational manuals; and focus groups. In addition, a review of existing PES for the OWI was completed to determine whether standards matched with the results of the task analysis.

RESULTS: Five critical tasks were identified: transfer from the vessel to the Transition Piece; ascent of the internal ladder; manoeuvre through hatches; torque and tensioning; and hauling a

casualty up the tower. With the exception of aerobic capacity, the physical components required by Technicians are not assessed by the current medical standards, nor are these assessments standardized across companies. **CONCLUSIONS:** The job task analysis undertaken can be used to inform decisions regarding the physical fitness requirements (selection), assessments and training of Technicians, with a view to ensuring that they are physically capable of undertaking the critical tasks without undue risk of injury to themselves or others.

Key Words: Subject Matter Experts, Wind Technicians, Physically Demanding Tasks, Ladder climbing.

Introduction

Since 2003 there has been a large-scale commercial development of offshore wind farms [1]. The largest offshore wind farms are currently located in northern Europe, especially the UK and Germany, which together account for approximately 84% of the total offshore wind power installed worldwide [2]. When operational the turbines are serviced and maintained by Technicians who are typically responsible for: testing electrical components and systems, as well as mechanical and hydraulic systems; inspecting the exterior and physical integrity of towers; climbing towers to inspect or repair turbine equipment; collecting turbine data for testing or research and analysis; performing routine maintenance on wind turbine; and troubleshooting mechanical, hydraulic, or electrical malfunctions. With the industry in its infancy, many of the practices adopted to manage employee health and safety has been taken from the Oil and Gas Industry.

To assess an employees' physical ability to undertake their job, it is important to follow a valid methodology when developing a Physical Employment Standard (PES). In the UK, tasked-based PES have been introduced by the Military [3-5]; Fire and Rescue Service [6]; Maritime and Coastguard Agency [7]; Royal National Lifeboat Institution [8-10], and recommended to the Oil and Gas Industry [6]. These standards generally base the suitability for employment on the

physical and physiological components associated with the safe and successful completion of tasks that are considered generic and critical, for a specific job, thus employment is free from age and sex discrimination [11-12]. The critical tasks are identified through a job task analysis which evaluates an occupation to determine the frequency, importance and physical demand of the tasks involved [13-16]. A PES can include measures of strength, endurance, anthropometrics, flexibility, motor skills and cardiovascular and metabolic fitness. These are most commonly assessed through either direct task simulation of the job or predictive tests, [4-6; 8-10; 14; 17; 18] should reflect job criteria and therefore not influenced by factors such as age or sex [11].

The aim of this study was to undertake a job task analysis for Technicians performing maintenance tasks of operational turbines, in the Offshore Wind Industry (OWI). In addition, the validity of the current technician medical fitness tests were reviewed.

Methods

Job Task Analysis

The job task analysis in the present study was applied to Technicians working on operational turbines and did not apply to employees associated with turbine construction. The terminology used throughout the job task analysis was based on the Figure 1.

INSERT FIGURE 1 HERE

The physically demanding tasks undertaken by Technicians in the OWI during a typical working day and in emergency situations were broken down into component jobs which were then described in terms of: frequency, duration, rest breaks, clothing ensembles, environmental conditions and the methods of best practice (MOBP). The job task analysis was completed by: observations of Technicians performing tasks; the research team undertaking tasks; reviewing operational manuals; the measurement of equipment mass and/or dimensions; and a focus group with an expert panel. The expert panel comprised of nine members of the offshore wind industry, who all have various experiences and job roles (Table 1). The Subject Matter Expert (SMEs) fulfilled at least one of the seven criteria detailed in Table 2. Collectively, the nine SMEs fulfilled all seven criteria.

INSERT TABLE 1 HERE

INSERT TABLE 2 HERE

The results of the job task analysis were sent to the G+ committee (which consists of representative for each of the member Offshore Wind Organizations) for comment and endorsement.

Critical tasks included the most physically demanding activities associated with two groups of Technicians, these were Service

Teams (on average these teams are made up of three Technicians [range 2 to 4], of which one will be a Team Leader) and Troubleshooting Teams (two Technicians).

Review of the current PES for Offshore Wind Technicians

Five companies from G+ responded to an email asking if any internal fitness standards/tests were implemented within their organization. Companies were asked: What these tests are? What are the pass scores? Where do these data come from?

Results

Job Task Analysis

A detailed qualitative description of the tasks associated with the OWI are presented.

An overview of shift patterns and the working day

The majority of operational servicing and maintenance work is carried out March to September, with a reduced number of Technicians working during the winter months of October to February. A number of different shift patterns are implemented across the industry (Table 3). During these shift patterns “bad weather days” could mean Technicians go through periods of not working. Some organizations automatically stand Technicians down

after 9 days of continuous work and Technicians can stand themselves down if feeling excessively fatigued.

INSERT TABLE 3 HERE

The start of the working day is often tide dependent and varies throughout the shift pattern, e.g. departure time may vary between 0300 and 1500. In general, all Technicians work a 12-hour day, which can be spent on one turbine or changing between turbines on up to three transfers.

The tasks

Based on the qualitative analysis undertaken five tasks were deemed to be the critical for Technicians in the OWI, these are: transfer from the vessel to the transition piece (TP); ascent of the internal ladders; manoeuvre through hatches; torque and tensioning; and hauling a casualty up the tower. A summary of the critical tasks are detailed in Table 4, with full descriptions provided in the following sections.

INSERT TABLE 4 HERE

Transfer from the vessel to the turbine

The time taken to travel between the port and turbine can vary depending on the; distance of the field from the port; weather conditions; the number of Technicians aboard (up to 12 Technicians); sea state and sickness (if vomiting is reported, a vessel

will return to port). Therefore, the transfer of Technicians can take 3 to 4 hours.

Once the vessel arrives at the turbine there are several transfer methods from the vessel onto the turbine, these are dependent on the design and location of the turbine. The SMEs stated the most physically demanding method requires Technicians to transfer from the vessel to the TP (Figure 1 & 2) via an external vertical ladder, wearing: a lifejacket (~2.3 kg), personal protective equipment ([PPE] safety boots, gloves, glasses, climbing helmet [~0.5 kg]), high visibility clothing, harness and attachments (~6 kg), and potentially a sea survival suit (~2.5 kg).

Technicians step from the vessel onto the external ladder. Sea state and thus the movement of the vessel affects: the size of the initial step onto the ladder; the speed Technicians step from the vessel to the external ladder and distance the Technicians will have to climb up the external ladder. SMEs reported that these component tasks require coordination and agility. Technicians must be able to achieve hip flexion past 90° to transfer onto the external vertical ladders, this highlights a need for hip mobility. The rungs of the ladder are typically diamond shaped (each side of the diamond shaped rung = 40 mm) with 330 mm between each rung (mid-point to rung mid-point), 500 mm internal width (to the inside of the vertical rail) and 680 mm external width (to the outside of the

vertical rail; Figure 2). The duration of the initial climb onto the TP was estimated by the SME groups to take no more than 2 minutes and is proceeded by a rest. The procedures described are reversed when disembarking the TP onto the vessel.

The condition of the ladder rungs (i.e. build-up of deposits and wet rungs); feelings of seasickness; the clothing worn (i.e. a sea survival suit restricting movement); previous climbs (i.e. fatigue); and light conditions, will in addition, affect the nature and demand of the transfer onto the external ladder.

Climbing the tower and maneuvering through hatches

The total height from the TP to Nacelle ranges from 80 m to 120 m (Figure 1). Depending on the make and model of turbine, SMEs estimated that there could be between 5 to 10 ladders of varying height between the climb from TP to the Nacelle.

Generally, the internal ladders have an internal width of 400 mm; external width of 470 mm, with 300 mm between rungs (mid-point to rung mid-point), but may vary depending on the make and model of turbine.

Prior to the Nacelle ascent, teams typically rest for a minimum of 10 minutes. During the ascent one Team member will climb a ladder at a time, this technician will be wearing full PPE and a climbing harness attached to a safety line and/or a fall arrest. The SMEs

reported that whilst one of the Team is climbing the other team members are resting. There are no time constraints placed on a Team ascending the tower, and they can rest either at the points between ladders or whilst climbing. The intermittent nature of this task might suggest that the task could require both the aerobic and anaerobic energy systems. The SMEs stated that the MOBP for climbing the ladder was with two points of contact (e.g. using and alternate hand to foot action), this was proposed to be easier and more efficient and require Technicians to be coordinated, agile and mobile.

Operationally, the SMEs stated the Lead Technician climbs to Level A2 (approx. 10 m), whilst the other two Technicians would climb straight to Tower Tower (approx. 30 m, Figure 1), which would take 3 to 4 minutes, suggesting climbing rates between 25 rungs.min⁻¹ to 33 rungs.min⁻¹. Technicians tend to rest on reaching Tower Tower, until the second and/or third technician has reached this level. SMEs reported a significant fatigue in the forearms approximately ¾ of the way up the Tower Tower, which suggested a requirement for local muscular endurance. The number of rests on the ladder increases, and climbing rate decreases to ~20 rungs.min⁻¹ as the climb progresses up past A4 to the Yaw and into the Nacelle.

Movement through hatches is a critical task when ascending the turbine. Hatches vary in size, orientation and mass within a turbine and across turbines, depending on the make and model (these were

not quantified at the time and SME were unable to provide estimations), thus Technicians are required to adopt various positions when opening and ascending hatches that require strength, mobility, agility and coordination.

On reaching the Nacelle, teams have a minimum of 10 minutes' rest before beginning the other physically demanding tasks. The number of complete ascents and descents of the Tower varies from one to three over the course of the day.

Torque and Tensioning

The SMEs reported that the most physically demanding task Service Teams were required to complete was bolt torque and tensioning, which forms approximately 20% of a turbine service time. Service Technicians manually handle the tensions heads used to tighten bolts of various weights, in a variety of awkward positions whilst standing, kneeling or seated, depending on the dimensions of the work space, suggesting the requirement of mobility. The heaviest torque wrench used was measured at 7 kg and the heaviest tension head 19 kg (Table 4). SMEs stated this was a whole body task, with fatigue accumulating in the shoulders, torso and lower back indicating a need for muscular strength and endurance.

INSERT TABLE 5 HERE

Hauling a casualty up the turbine

In an emergency situation, the most physical demanding casualty evacuation was identified by SMEs as hauling a casualty up to the top of the turbine for extraction from the helipad. The Technicians are required to climb (without rest) to where the casualty is located, this could be the top of the turbine and therefore would require a straight ascent of the tower. This suggests a requirement for a higher level of aerobic and anaerobic fitness than those ascending the turbine under non-emergency situations.

Upon reaching the casualty, Technicians must manual handling them into a stretcher and haul the casualty up the turbine for extraction from the helipad. The manual hauling method for this task is a 6 to 1 pulley, supported by work positioners that have a reach of 4 m. Therefore, the minimum distance Technicians would be expected to haul a casualty is 4 m, although in some cases this would have to be repeated multiple times.

Casualty mass is limited by the maximum load the climbing kit can withstand i.e. 136 kg (casualty plus PPE), not including the spinal board [approx. 6 kg to 8 kg] and/or basket stretcher [approx. 10 kg to 13.5 kg]). The need to haul these loads repeatedly will require muscular strength, endurance and coordination.

Other physically demanding tasks

Four tasks that occur during each shift are: manual handling of loads up to 27 kg in a single person lift up to a height of 1 m; manipulation of loads on a crane; operation of brake calipers in the Yaw and fixing lights on a ladder at various angles. The SMEs subjectively reported that the physical demands of these tasks did not supersede those documented above.

The current PES for Offshore Wind Technicians

Five OWI organizations stated that they applied one of two off the shelf medical policy documents [20, 21], which assess the two fitness parameters of aerobic fitness (Table 6) and a subjectively rated assessment of mobility. Currently, all five organizations implement medical standards as opposed to a PES.

INSERT TABLE 6 HERE

Two different aerobic standards are presently used by the five organizations. These include an aerobic standard where the pass mark is a predicted oxygen uptake of $35 \text{ mL.kg}^{-1}.\text{min}^{-1}$ or a pass of “good”, as stipulated by the normative data of the Chester Step Test. The aerobic standard of $35 \text{ mL.kg}^{-1}.\text{min}^{-1}$ derived from the Oil and Gas Industries [22] recommendation for Emergency Response Teams (ERT).

Discussion

This is the first study to identify tasks considered physically demanding and critical for Technicians working in the OWI. Five critical tasks were identified: transfer from the vessel to the TP; ascent of the internal ladder; manoeuvre through hatches; torque and tensioning; and hauling a casualty up the tower. It is proposed that the identified tasks require a range of physical attributes including: mobility, upper and lower limb strength, strength-endurance, aerobic and anaerobic capacity (Table 5).

The critical task of ladder climbing yielded conflicting results regarding the MOBP. SMEs reported that Technicians climb a ladder with two points of contact, this is in contrast to the directive for the Health and Safety Executive (HSE) guideline for the safe use of step ladders and ladders, which advocates three points of contact

[23]. It should be noted that this guideline appears to be for those free climbing, not those attached to a fall arrest harness. Similarly, the “Good practice Guideline for Working at Height in the Offshore Wind Industry” [24] states “the probability of falling can be minimized by limiting the activities that are carried out from a ladder, and ensuring that users maintain three points of contact with the ladder”. Therefore, the MOBP used by Technicians to climb ladders requires further investigation. In order to quantify the physical demands of the critical tasks the OWI would need to agree minimum acceptable operating procedures and MOBP for tasks where the load and repetitions could not be quantified objectively [11].

It was not possible to determine the MOBP or minimum performance standards for all tasks presented. For example, due to variations in turbines, standardizing certain tasks such as the transfer from the vessel is extremely difficult. Further analysis that was beyond the scope of this project would be required to assess: the impact various ladder conditions, brought about by the environment, (e.g. wet slippery rungs) on the demands of transferring from the vessel to the; the impact of sea state on the physical requirements required to transfer onto the ladder; orientations and forces required to lift hatches. Torque tensioning is a common manual handling task and as such would fall under the Health and Safety Executive (HSE)

guidelines on “Getting to grips with manual handling” [25] and Rapid Entire Body Assessment (REBA) [26], which would ultimately set the performance standards from which a PES could be applied.

Currently assessments of fitness are prescribed within medical standards, where the focus is to assess health rather than the physical ability of Technicians to undertake the jobs of the OWI. The tests within these medical standards include a simple step test to predict maximal aerobic capacity ($\dot{V}O_{2max}$) and subjective range of movement tests. In some instances, Offshore Wind Organizations adopt the Oil and Gas UK Medical standards that set a minimum predicted $\dot{V}O_{2max}$ requirement of $35 \text{ mL.kg}^{-1}.\text{min}^{-1}$, based on the critical task of ladder climbing in the Oil and Gas industry [22]. Whilst those working in the Oil and Gas Industry may be required to undertake a critical task such as ladder climbing, the performance of this task, the duration, rate and clothing ensembles worn are different from that of Technicians in the OWI. Thus, the problem with using the Oil and Gas industry pass score is that it lacks content validity [12]. An alternative approach adopted in the RenewableUK Medical Fitness to Work suggests an aerobic capacity pass/fail recommendation based on normative data that estimated aerobic capacity in those working on wind turbines should be at least $35 \text{ mL.kg}^{-1}.\text{min}^{-1}$ [27]. Basing an aerobic score on normative data may

highlight individuals with conditions that compromise safety e.g. a risk of falling or sudden incapacity. However, it does not necessarily ensure capability for regular climbing of vertical ladders and for working in hot and/or confined spaces. These are yet to be quantified and could exceed what is the population norm. This would require further investigation to fully understand the physical requirements of self-paced ladder climbing, if a minimum operational standard for climbing ladders could not be agreed within the OWI.

Finally, some organizations stated they applied a score of “good”, on a predictive step test, meaning based on the error of the test that an employees’ actual aerobic capacity could range from 33 mL.kg⁻¹.min⁻¹ to 59 mL.kg⁻¹.min⁻¹. Whilst this is acceptable for health-based screening, it does not necessarily ensure that employees have the required aerobic fitness to successfully undertake the critical tasks of a technician. In addition, having a range of possible scores based on age and sex means that selection is both age and sex biased. For example, a “good” score for a male aged 20 to 29 results in a minimum estimated aerobic capacity of 44 mL.kg⁻¹.min⁻¹ (range 44 mL.kg⁻¹.min⁻¹ to 55 mL.kg⁻¹.min⁻¹), whilst a female aged 40 to 49, who may be expected to undertake the same critical task as the male, would have a minimum estimated aerobic capacity of 34 mL.kg⁻¹.min⁻¹ (range 34 mL.kg⁻¹.min⁻¹ to 42 mL.kg⁻¹.min⁻¹) [28]. Having a standard that allows a range in test scores, such as those described

above, are generally considered inappropriate in the context of developing a task-based PES, where standards are based on the physical demand of the critical tasks, thus ensuring selection is fair and unbiased [11].

The job task analysis undertaken can be used to inform decisions regarding the physical fitness requirements, assessments and training of Technicians, with a view of ensuring that they are physically capable of undertaking the critical tasks without undue risk of injury. Further investigation would be required to standardize the MOBP and quantify the physical demands of the critical tasks to develop a task based PES. In order to do this the industry would need to agree minimum acceptable operating procedures for tasks in which the loads and repetitions cannot be quantified.

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Table 1. Demographics of the nine Subject Matter Experts.

Job Title	Years in the industry	Years working as a technician	Age	Sex
Head of HSE* Offshore Technologies & Wind Construction	20	n/a	47	Male
Shift manager	8	4	44	Male
Site technician wind power	4.5	4.5	23	Female
HSE* Advisor Wind Generation	6	-	51	Female
Vessel Master	8	-	50	Male
Offshore operational engineer	4	4	32	Female
QHSE* Safety Advisor	8	-	45	Male
Senior Technician	7	7	43	Male
Authorising Officer	7	5	36	Male

*HSE = Health Safety and Environment; QHSE = Quality, Health, Safety, and Environment.

Table 2. Criteria for Subject Matter Experts adapted from Blacklock et al [19].

Criteria	
1.	Experience performing the task onshore
2.	Experience performing the task offshore
3.	Experience performing the task during an emergency situation
4.	Experience in a position of leadership where you have directed other employees to perform the task and have observed the task being performed
5.	Have witnessed the task being performed in an acceptable manner
6.	Have witnessed the task being performed unsuccessfully and can attest to the reasons for, and the consequences of, this failure (e.g. A person was not fit enough to climb the ladder)
7.	Witnessed and/or performing the task using several techniques and can comment on the advantages and disadvantages of these techniques

Table 3. Example shift patterns provided by the Subject Matter Experts.

Shift Pattern		Employee Type
Days On	Days off	
4	4	Organisational employee
6	3	Site based
14	7	Travelling technician (contractor)
7	7	Organisational employee, Site based and Contractors
14	14	Technicians living on board a vessel – deep water fields

Table 4. A summary of the critical tasks for Technicians in the offshore wind industry.

Task	Team Size	Frequency	Duration	Distance	Climbing Equipment/ PPE	Loads Lifted	Fitness Component/s	Data collected from:
Transfer from the vessel to the turbine	2 to 4 people	Up to 3 times per day	Dependent on sea state < 2 mins	Step from vessel = variable Ascend a ~10 m ladder	HA, SB, GG, CH, HVC, SSS <i>Total = ~ 11.3 kg</i>	None*	Mobility, Agility Coordination, Anaerobic	SME; video resource
Ascent of the tower	2 to 4 people	Up to 3 times per day	No time restraints Suggested 3 to 4 mins	80 - 120 m (dependent on turbine model)	HA, SB, GG, CH, HVC <i>Total = ~ 8.8 kg</i>	None*	Mobility Coordination Anaerobic, Aerobic Muscular endurance	SME; Researchers undertaking the task; Operational manuals
Manoeuvring through hatches	2 to 4 people	Multiple	Not quantified	None stated	HA, SB, GG, CH, HVC <i>Total = ~ 8.8 kg</i>	The weight of the hatch. These vary based on location and the make and model of the turbine	Mobility, Agility Coordination Muscular strength	SME
Torque tensioning	1	20% of the time working on one turbine	Not quantified	N/A	HA, SB, GG, CH, HVC <i>Total = ~ 8.8 kg</i>	Up to 19 kg	Mobility Coordination Muscular strength Muscular endurance	SME; Researchers undertaking the task; measurement of equipment
Hauling a casualty up the turbine	2 (only one hauls)	Not quantified	Not quantified	Climb to the casualty, up to 120 m Min haul distance 4 m (repetition dependent on casualty location in the turbine)	HA, SB, GG, CH, HVC <i>Total = ~ 8.8 kg</i>	SB (6-8 kg) or BS (10-13.5 kg); Casualty mass max = ~127.2 kg; Kit = ~8.8 kg Total = ~25 kg based on 1 to 6 pulley system	Mobility Coordination Anaerobic, Aerobic Muscular endurance Muscular strength	SME; Operational manuals; measurement of equipment

Key: LJ = Life jacket; HA = Harness and attachments; SB = Safety Boots; GG = Gloves and Glasses; CH = Climbing helmet; HVC = High visibility clothing; SSS = Sea survival suit; SB = Spinal board; BS = Basket stretcher. * None = no additional load other than climbing equipment and PPE.

Table 5. Tension heads and lifting requirements

Tension head mass (kg)	Lifting requirement
8.5	The 8.5 kg and 9 kg tension heads are often used in line with the shoulder (approx. 1.6 m). This can often require the tension head to be held in a single hand.
9	
13	Generally used horizontally from chest height (approx. 1.5 m). This can sometimes require the tension head to be held in a single hand.
19	These are predominantly used at the Tower Tower section (Figure 1) of the turbine. The tension head is normally lifted to chest height, using an upright row movement.

Table 6. Overview of the current medical from the five respondents.

Organisation	Standard and test used to assess fitness	Level/Pass criteria
1	Oil & Gas Offshore Medical – Chester Step test	35 mL.kg ⁻¹ .min ⁻¹
2	Chester Step test	Not reported
3	Renewables UK: Medical Fitness to Work – Wind Turbines – Chester Step test	35 mL.kg ⁻¹ .min ⁻¹
4	Oil & Gas Offshore Medical – Chester Step test	Level “Good”
5	Oil & Gas Offshore Medical – no aerobic test	N/A

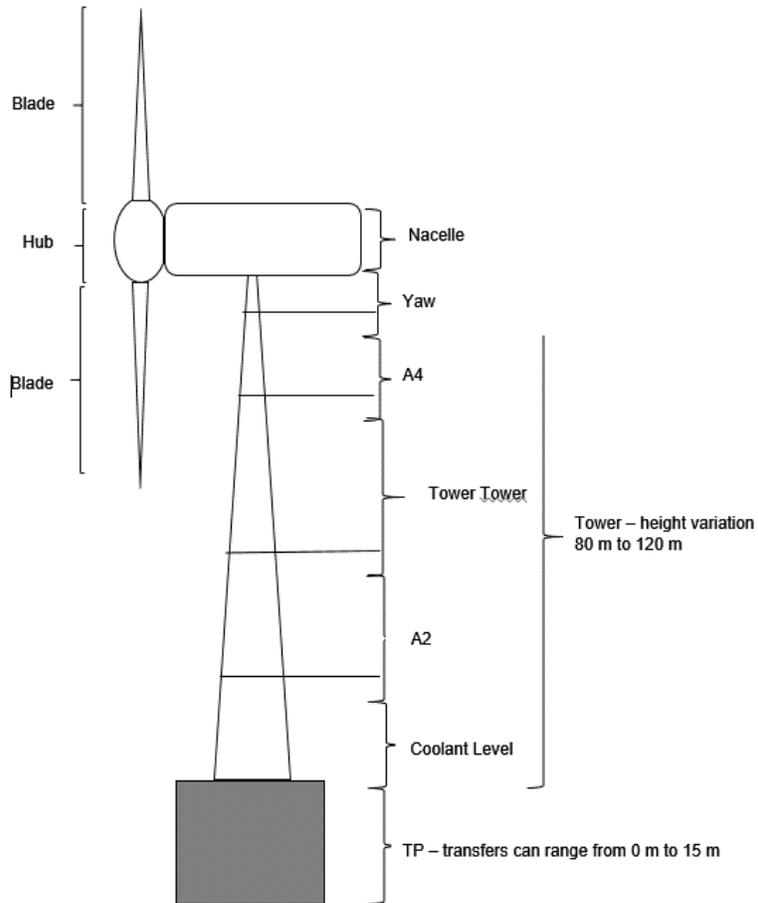


Figure 1. Schematic of an offshore wind turbine. The schematic is not to scale with variations occurring in all aspects across the industry. The model is based on a 3.6 Offshore Turbine.



Figure 2a & 2b: Examples of the external ladder on a turbine. NB.

Figure 2a depicts a vessel up against an external ladder.