PivotBuoy

An Advanced System for Cost-effective and Reliable Mooring, Connection, Installation & Operation of Floating Wind

Call identifier: H2020-LC-SC3-RES-11-2018

D6.2: Update of Reliability, Health & Safety and Environmental Assessment of the PivotBuoy system

Due Date of Deliverable: 30/06/2020
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Lead partner for deliverable: INTECSEA

Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including Commission Services)	
CO	Confidential, only for members of the consortium (including Commission Services)	

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Document History

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30/06/2020	1.0	For information

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1 EXECUTIVE SUMMARY

This report is the second deliverable of Task 6.1 (Hazard and Reliability Aspects), Task 6.2 (Health & Safety Aspects) and Task 6.3 (Environmental Aspects). It presents an update of the Failure Mode, Effects and Criticality Analysis (FMECA) and of the the HAZard IDentification (HAZID) of the PivotBuoy system. This report builds on the assessments reported in the deliverable D6.1 "Identification of failure modes and initial reliability, health & safety and environmental assessment of the PivotBuoy system" [Ref 1], which was issued in September 2019.

A general objective of Work Package 6 is to identify critical failure modes and de-risk the development of the PivotBuoy system. This is achieved by means of a continuous process of risk identification, evaluation and mitigation during the project lifecycle. Deliverable 6.1 presented an initial technology assessment and initial FMECA based on the design definition achieved dring the first months of the PivotBuoy project. These initial assessments allowed the design team to focus their efforts on eliminating ('designing out') significant risks.

The FMECA has been updated frequently during the engineering phase as and when new design data has become available. Key milestones in this process have been the Detailed Design Reviews (DDR) during which the designs have been presented to and discussed amongst the broader PivotBuoy consortium team. In addition to these formal reviews, numerous FMECA sessions have been held with focus on a particular system component or sub-component. The responsible engineers for these components have contributed actively during these sessions. The updated FMECA register is included in this report as an appendix. This FMECA register reflects the design status as of mid-June 2020.

In addition to the FMECA, an initial HAZID of the offshore transportation and installation methodology was performed in conjunction with the DDR2 session. The hazards identified during this session will be addressed in the installation procedures.

Deliverable D6.3, to be issued at the end of the project will present a further update on reliability, health and safety and environmental assessments of the system.

2 INTRODUCTION AND OVERVIEW

The *PivotBuoy Project: An Advanced System for Cost-effective and Reliable Mooring, Connection, Installation & Operation of Floating Wind* (referred to as PivotBuoy project) is a project that will develop a prototype of the "PivotBuoy" system to demonstrate its potential to reduce the Levelized Cost Of Energy (LCOE) of floating wind. The PivotBuoy is an innovative subsystem that aims to reduce the costs of mooring systems and floating platforms, that allows faster and cheaper installation and that supports a more reliable and sustainable operation. The system will be installed at the PLOCAN test site (Gran Canaria) to validate the concept, by integrating a prototype of the mooring system in a downwind floating platform that will be developed by X1 Wind.

The objective for Work Package 6 (Risk Assessment including Reliability, Environment, Health & Safety) activities is to de-risk the system development by identifying critical failure modes and analysing system reliability. Due to the very limited application of floating wind systems world-wide, there currently is little data available in the public domain on risks and failure modes specifically relevant for floating offshore wind systems. However, there is a wealth of experience and data available from cross-cutting fields from other relevant sectors. Regarding the PivotBuoy subsystem and its components, experience from the oil & gas sector and in particular from design, installation and operation of Single Point Mooring (SPM) systems, Tension-Leg Platforms (TLP) and dynamic riser and cable systems have been applied to identify potential risks. This experience data includes relevant information on failure modes and events.

The work on Task 6.1 of Work Package 6 started during the preliminary design phase by performing a technology assessment for the concept system design following the technology qualification methodology described in DNVGL-RP-A203. This resulted in a technology categorization rating for each major component of the PivotBuoy system. Subsequently, an initial Failure Mode Effect and Criticality Analysis (FMECA) was performed to chart the probability of system and component failure modes against the severity of their consequences. Both the technology qualification assessment and the FMECA are tools to support the systematic identification and management of technical risks during a project. As stand-alone documents (registers) they have limited value. However, they are highly valuable when integrated into the overall design process where they can be utilized to assess a developing design in terms of technical risks on a continuous basis. The continuous feedback allows risks to be 'designed out' at an early stage, which is the most effective means of risk reduction and also the most cost-effective.

The initial FMECA findings for PivotBuoy were fed into the detailed design phase so that the identified risks could be addressed and mitigated to the extent practicable. This initial work is presented in deliverable D6.1 "Identification of failure modes and initial reliability, health & safety and environmental assessment of the PivotBuoy system" [Ref 1], which was issued in September 2019.

This report is the second deliverable under Work Package 6 and documents the work performed to update, to maintain and to implement the results of reliability, health and safety and environmental risk assessment of the PivotBuoy system. The main vehicle for this effort continues to be the FMECA register, which has been maintained as a 'live' document throughout the design process; i.e. the risk assessment has developed in parallel with the design itself. This has been an interactive and iterative process whereby initial designs were assessed and associated risks were identified. Identified risks

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were then addressed in the design, and further rounds of FMECA sessions were held to review the status. Where justified, risk ratings were adjusted to reflect the mitigating actions taken, and new actions were assigned where appropriate.

The assessments reported in this document are based on the system design as of mid-June 2020. At the global level, this design is largely unchanged from the design presented at DDR2 held in March 2020 (see Figure 1 and Figure 2). Further information on the design status can be found in project deliverable D2.3 "*Detailed design review*".

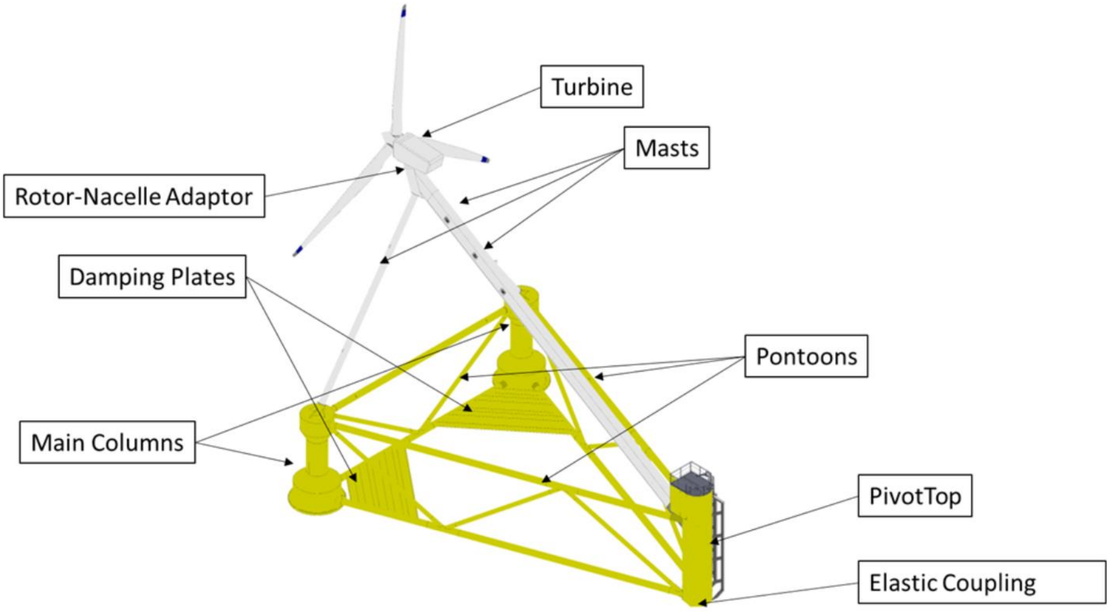

Figure 1. Detailed design as reflected in the FMECA

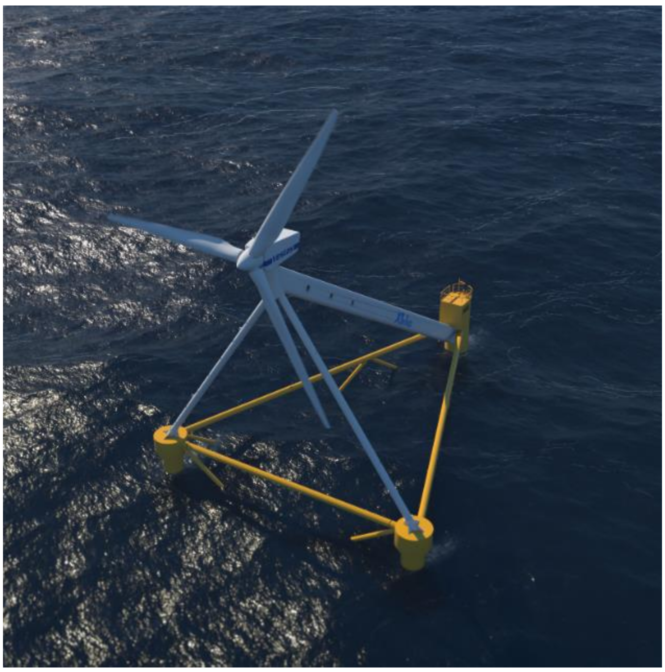

Figure 2. Rendering of Design

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The FMECA process has been a collaborative effort with input from the consortium members. Sessions have been held both as part of planned project meetings and as stand-alone meetings. The results of these sessions have been documented directly in the FMECA register.

Separately to the FMECA, a Hazard Identification (HAZID) review has been performed with focus on the installation methodology. This was done on 5 March 2020 in conjunction with the detailed design review and was attended by the consortium partners [Ref 2]. The purpose of the HAZID was to identify the risks associated with the transportation and installation of the PivotBuoy unit offshore Gran Canaria. A set of HAZID guidewords was used to stimulate the discussions and to ensure identification of typical risks. The HAZID register will serve as input to the detailed installation procedures and will be re-visited at a later date once the procedures are available.

The remainder of this report describes in further detail the background for the risk assessment approach taken and the results of the assessments performed.

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3 FMECA PROCESS

3.1 Purpose and method - general

To better prioritize the design development efforts, a method is required that not only categorizes the technology complexity but that also considers the consequences of component malfunction to system performance and to the project in general. As described in D6.1 "*Identification of failure modes and initial reliability, health & safety and environmental assessment of the PivotBuoy system*" [Ref 1], the selected failure mode identification technique for PivotBuoy is the Failure Mode, Effects and Criticality Analysis (FMECA) as described in DNVGL-RP-A203.

The objective of an FMECA is to identify relevant failure modes with underlying failure mechanisms for the components of a physical system. The level of detail of the FMECA is therefore governed by the level of detail of the design. The output of the FMECA is a list of possible failure modes for each of the main components and sub-components of the PivotBuoy system and a quantification of the associated risks (risk being the combination of failure probability and consequence of failure). Subject matter experts identify the possible failure modes and their judgement is applied to assign probability and consequence values to each identified failure mode.

The entries in the FMECA register can be sorted in order of risk ranking (i.e. High to Low), and treatment of the highest risks can be given priority during the design process. As a design pogresses, the FMECA is updated by re-assessing the components and adding entries to the register to reflect the latest design details. Good practice dictates that entries are never fully deleted from the register so that traceability is maintained.

3.2 System components and sub-components

The main component breakdown applied for the FMECA has developed over time, which reflects the progression of the design. The current component and sub-component definitions are listed below. These are not expected to change any further.

The nacelle / turbine is not included here as a component since it is not part of the project scope. This part of the structure will be purchased as fully functional (re-cycled) component and is not part of the scope of this risk identification process.

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Main Component	Sub- components
Foundation	Structure - main
	Structure - tether interfaces
	Seabed interface
	Scour protection
Mooring	Upper tether joints
	Tendons (tethers)
	Lower tether joints
Pivot Bottom	Structure - main
	Structure - tether interfaces
Yaw System	Bearing arrangement
	Elastomeric mount / coupling
	Rubbers
	Steel components
	Studbolts
Pivot Top	Structure - main
	Center shaft
	Deckhouse / technical room
	Upper deck
	Boat landing
Pontoons & Masts	Super-structure - pontoons - wetted
	Super-structure - masts - dry
	Rotor-Nacelle-Adapter (RNA)
	Walkway thru PivotMast
	Heave damping plates
Main Columns	Ballast compartments
	Filling pump
	De-ballasting pump
	Piping
	Sensors
	Control unit
	Vent
Electrical Power	Cable - RNA-buoy - dry
	Electrical transfer unit
	Riser system - wet
	Cable on seabed
	Power end location
Utilities	Control room
	Lightning protection
	Power
	Nav lights & signal
	Safety (fire)
	SCADA

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3.3 Risk categories

The risk category, as combination of probability and consequence, is assigned following the guidelines given in DNVGL-SE-0422

The probability class assignment is done based on the values given in Table 1.

Table 1: Probability classes

Class	Name	Description	Reference
1	Very low	Negligible event frequency	Accidental
2	Low	Event unlikely to occur	Strength / ULS
3	Medium	Event rarely expected to occur	Fatigue / FLS
4	High	One or several events expected to occur during the lifetime	Operation low frequency
5	Very high	One or several events expected to occur each year	Operation high frequency

The consequence classes are as defined in Table 2.

Table 2: Consequence classes (floating turbine or component)

Class	Description of consequences (impact on)				
	Safety	Environment	Operation	Assets	Cost (€)
1	Negligible injury or health effects	Negligible pollution or no effect on environment	Negligible effect on production (hours)	Negligible	1k
2	Minor injuries or health effects	Minor pollution / slight effect on environment (minimum disruption on marine life)	Partial loss of performance (retrieval not required outside maintenance interval)	Repairable within maintenance interval	10k
3	Moderate injuries or health effects	Limited levels of pollution, manageable / moderate effect on environment	Loss of performance requiring retrieval outside maintenance interval	Repairable outside maintenance interval	100k
4	Significant injuries	Moderate pollution, with some cleanup costs / Serious effect on environment	Total loss of production up to 1 m (€)	Significant but repairable outside maintenance interval	1m

The combination of probability and consequences results in a risk ranking as shown in the table below. In general, actions required to close a specific entry in the FMECA register depend on the risk ranking, as follows :

- Low risk : Tolerable, no action required
- Medium risk : Mitigation and improvement to be considered to reduce risk
- High risk : Not acceptable, mitigation and improvement required to reduce risk

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Table 3: Risk Ranking

	Consequence				
Probability	1	2	3	4	5
5	Low	Med	High	High	High
4	Low	Med	Med	High	High
3	Low	Low	Med	Med	High
2	Low	Low	Low	Med	Med
1	Low	Low	Low	Low	Med

3.4 FMECA Update Process

As reported in deliverable D6.1 [Ref 1], the FMECA process for PivotBuoy started with the preparation by INTECSEA of an initial register, which then formed the basis for the the first plenary session involving the other consortium members. This plenary session took place in Barcelona on the 17th and 18th of July 2019, and the results of this session were used to populate and to update the FMECA register. The first formal issue of the FMECA register was as an appendix to deliverable D6.1.

Since its first formal issue, the FMECA register has been maintained as a 'live' document. This means that updates were made to the register as and when new design information became available. Furthermore, focused sessions have been held to assess in greater detail specific components of the PivotBuoy system. These sessions typically have comprised a presentation of the design by the responsible lead engineer followed by FMECA assessment facilitated and scribed by INTECSEA.

The general timeline leading up to this report has been:

Dates	**FMECA Update Activity**
5 December 2019	First Detailed Design Review (DDR1) session (on-line meeting) covering Pivot mast, side masts, pontoons and PivotBottom
December 2019 – January 2020	Desktop update of FMECA by INTECSEA based on design information presented during DDR1
30 January 2020	Focused FMECA session (on-line meeting) on active ballast system in main columns In attendance: X1Wind, DNVGL and INTECSEA
19 February 2020	Focused FMECA session (on-line meeting) on Yaw system and the Elastic Coupling System *In attendance: X1Wind, ESM, DNVGL and INTECSEA*
March – April 2020	Desktop update of FMECA by INTECSEA based on design information presented at DDR2
5-6 March 2020	Second Detailed Design Review (DDR2) session in Barcelona. Overview of FMECA satus presented to consortium partners
22 April 2020	Focused FMECA session (on-line meeting) on anchor and mooring *In attendance: X1Wind, DNVGL and INTECSEA*
6 May 2020	Focused FMECA session (on-line meeting) on main columns *In attendance: X1Wind, DNVGL and INTECSEA*
20 May 2020	Focused FMECA session (on-line meeting) on masts and pontoons *In attendance: X1Wind, DNVGL and INTECSEA*

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Dates	FMECA Update Activity
27 May 2020	Focused FMECA session (on-line meeting) on foundations and mooring *In attendance: X1Wind, DNVGL and INTECSEA*
3 June 2020	Focused FMECA session (on-line meeting) on yaw system and elastomeric coupling *In attendance: X1Wind, ESM, DNVGL and INTECSEA*
11 June 2020	Desktop update of mitigative actions for the Utilities by X1Wind
11 June 2020	Desktop update of general mitigative actions by X1Wind
12 June 2020	Desktop update of mitigative actions for the main columns by X1Wind
16 June 2020	Desktop update of mitigative actions for the electrical systems by X1Wind
17 June 2020	Desktop update of mitigative actions for the masts, pontoons, PivotBottom and PivotTop by X1Wind

During May and June 2020, the focus of the FMECA process has progressed from identification of failure modes to the documentation of actions taken to mitigate the identified risks for each entry in the register. For most FMECA entries, actions to be taken were noted when the entry was first made; however, the development of the design meant that some of these actions became obsolete and new actions had to be added to reflect the latest design.

Various standard mitigative actions (e.g. implementation of quality control and development of detailed procedures) were seen to reappear for each main component, so a decision was taken to label these as 'general actions'. These general actions have been copied to a separate register so that actions taken can be recorded.

The responsibility for implementing mitigative actions for a system component is primarily with the responsible lead engineer for that component. The update of the FMECA register, to show the actions taken, therefore has been done largely by the lead engineers themselves as a desktop exercise.

3.5 Treatment of High Risk Findings

All entries in the FMECA register that were initially scored as High risk (see Table 3) were re-assessed to determine whether the mitigative actions taken (or to be taken) are sufficient to reduce the risk rating to Medium or Low. This is further discussed below. Entries that were initially rated Medium or Low risk have not been re-scored ; however, mitigative actions have been identified for these, and actual actions taken have been recorded in the register.

3.6 FMECA findings

The latest FMECA register is included as Appendix A to this report. This represents a snapshot of the FMECA process as per mid-June 2020. Some actions remain open, which is to be expected since

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fabrication is ongoing, and transportation / installation is yet to start. The Consortium will continue to track the status of the open FMECA entries and to implement the mitigative actions.

The FMECA register presently contains a total of 336 entries. This compares to 278 entries in the first formal issue in September 2019 [Ref 1]. The current 336 entries include 41 entries that have been set to ‘inactive’ (indicated by gray color shading); primarily due to changes in the design that have made them irrelevant. There are 295 ‘active’ entries in the register.

The following figures present the number and type of FMECA findings :

- Figure 3 summarizes the findings as per September 2019 [Ref 1].
- Figure 4 summarizes the findings as per the current FMECA register and based on the unmitigated risk
- Figure 5 summarizes the findings as per the current FMECA register and based on the mitigated risk (for entries originally designated as High risk, High risks that are no longer ‘active‘ are in the mitigated risk table arbitrarily set at consequence 1 and probability 1 to keep the total numbers consistent).

In each figure the risk categories are color-coded : low=green, medium=yellow, and high=red.

Number of occurences — total risks 278

Increase in consequence →

Increase in prob ↓

Conseq	1	2	3	4	5	total
Prob						
1	-	-	11	27	10	48
2	-	2	12	110	51	175
3	-	3	4	33	11	51
4	-	-	-	4	-	4
5	-	-	-	-	-	0
total	0	5	27	174	72	

Figure 3. Summary of FMECA findings – as per Ref 1 (September 2019)

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Number of occurences total risks 336

Increase in consequence →

Increase in prob ↓

Conseq	1	2	3	4	5	total
Prob						
1	-	-	11	21	15	47
2	-	6	17	131	64	218
3	-	2	11	42	10	65
4	-	-	2	4	-	6
5	-	-	-	-	-	0
total	0	8	41	198	89	

Figure 4. Summary of FMECA findings – Unmitigated Risk - June 2020

Number of occurences total risks 336

Increase in consequence →

Increase in prob ↓

Conseq	1	2	3	4	5	total
Prob						
1	1	-	11	22	15	49
2	-	6	17	135	71	229
3	-	2	11	43	-	56
4	-	-	2	-	-	2
5	-	-	-	-	-	0
total	1	8	41	200	86	

Figure 5. Summary of FMECA findings – Mitigated Risk – June 2020

The above figures show that the FMECA process has successfully reduced the number of high risk entries. By looking in detail at the mitigative actions taken for each entry (ref Appendix A), it is also evident that the FMECA process has contributed to achieving a more robust, lower risk design overall.

The FMECA register included in this report provides a snap-shot of the process as per mid-June 2020. Of the the 295 active entries in the register, 234 are considered closed (i.e. the actions identified to address the risk have been implemented). The remaining open entries (61) have actions that are ongoing or require implementation in a future phase. The FMECA register will remain a live document during the coming period, and open actions will be tracked to monitor progress towards closure.

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4 HEALTH, SAFETY & ENVIRONMENT

4.1 General

Both health & safety (H&S) and environmental aspects have been considered when updating the FMECA.

In general, it is a principal objective of the project to ensure that the design of the PivotBuoy facilities complies with applicable safety, health, working environment and environmental requirements. This applies during all phases of the project execution: from design through to installation and offshore operations. In addition, the ALARP principle will apply, meaning the risk will be reduced to "as low as reasonably practicable".

Ensuring a compliant design, is achieved through implementation of the following design considerations:

- Identifying risks early in the design process so that they can be managed. This is being done on PivotBuoy through the risk assessment activities described in this report.
- Apply 'Inherently Safe' design principles. This means that, where practicable, decisions are taken to 'design out' the identified risks. Passive solutions that reduce the probability component of a risk are preferred over active solutions that mitigate the consequence component of a risk. In other words, it is better to prevent an undesirable event altogether than to try to manage the consequences of such event once it has occurred. The FMECA register includes numerous examples of risks that have been effectively designed out.
- Minimizing the potential environmental impact during all phases of the project by considering environmental aspects.
- Maximizing the benefits of protection measures; both environmental and safety-related. This means selecting protection measures that are cost-effective, robust and practical to implement.

4.2 Health & Safety Aspects - HAZID

While an FMECA includes assessment of risk to personnel in the event of a component failure, it is not the best tool for assessing the direct risk to personnel (and environment) as a result of activities; e.g. activities required to transport and to install the PivotBuoy unit.

Risk to personnel during transportation and construction activities is better assessed and managed through Hazard Identification (HAZID) and Hazard & Operability Review (HAZOP). The former can be applied at a high level before detailed plans and procedures are in place, while the latter is best suited for assessment of detailed procedures and work plans.

In conjunction with the second Detailed Design review session held in March 2020 in Barcelona, INTECSEA facilitated a HAZID session centered around the draft general PivotBuoy transportation and installation methodology [Ref 2]. In general, the objectives of a HAZID are to identify main hazards, to review the effectiveness of selected safety measures and, where required, to expand the safety measures in order to achieve a tolerable residual risk. Given the status of the installation

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methodology at the time of the session, the main focus of the HAZID was on the first of the aforementioned objectives.

In advance of the HAZID session, INTECSEA prepared a list of guidewords (see Appendix B). These guidewords serve to trigger the participants to consider various potential hazard sources and thereby to propose specific hazard events. During the HAZID session, the responsible lead engineer for the installation methodology presented each of the main transportation and installation activities, and the attendees discussed specific relevant hazard events. These were recorded in the HAZID register (see Appendix C) and proposals were made on how to address the hazards. A total of 84 hazard scenarios were identified during the plenary session.

The HAZID register will be used as input to the development of the detailed transportation and installation procedures.

4.3 Environmental Aspects

Risks to the environment were considered during the initial risk assessment activities; however, the technology assessment and FMECA processes (being based on review at the component level), do not always identify all relevant environmental risks. A separate desk-top exercise has therefore been conducted with the specific objective to identify environmental risks during the three main phases of the project offshore; namely, installation phase, operating phase and removal phase.

The identified risks for each of these phases are listed below. These risks will be considered during the ongoing design process. Furthermore, environmental assessments will be performed as part of project Task 6.3, lead by PLOCAN, and where applicable the findings included in deliverables D6.2 and D6.3 as updates of subject report.

Environmental Impact Risks during Installation Phase:

- Potential for spills (e.g. fuels or hydraulic fluid) from marine vessels or installation equipment
- Above-water noise emissions from marine vessels exceeding established limits
- Below-water noise emissions from marine vessels, including the installation of the mooring system (anchor, cables, etc.), exceeding established limits
- CO_2 and NOx emissions from marine vessels and installation equipment exceeding established limits
- Disturbance of the seabed sediments and benthic species (for example during placement of structures or cables) beyond approved limits

Environmental Impact Risks during Operationing Phase:

- Potential for spills (e.g. bearing lubricant) from PivotBuoy system
- Potential for spills from operational support vessel
- Above-water noise emissions from turbine exceeding established limits
- Below-water noise emissions (vibrations) from turbine and mooring system exceeding established limits
- Above-water noise emissions from operational support vessel exceeding established limits

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- Below-water noise emissions (vibrations) from operational support vessel exceeding established limits
- CO_2 and NOx emissions from operational support vessel exceeding established limits
- Harm to aquatic fauna (fish, cetaceans, etc)
- Harm to bird life
- Interaction with other users of the marine space (fishing, shipping, etc.)

Environmental Impact Risks during Removal Phase:

- Potential for spills (e.g. fuels or hydraulic fluid) from marine vessels or equipment
- Above-water noise emissions from marine vessels exceeding established limits
- Below-water noise emissions from marine vessels, including the decommissioning of the mooring system (anchor, cables, etc.), exceeding established limits
- CO_2 and NOx emissions from marine vessels and equipment exceeding established limits
- Disturbance of the seabed sediments and benthic species (for example during removal of structures or cables) beyond approved limits

It is worthy to note that an Environmental Impact Assessment has been outsourced by PLOCAN to fulfill the requirement pointed by the Law to manage the electrical consenting of national administration. Taking advantage of this document, these risks, which have been identified, will be reviewed and updated in deliverable 6.3 Final reliability, H&S and Environmental.

5 CONCLUSIONS AND WAY FORWARD

This report presents an update of the hazard identification and potential failure modes, reliability and health and safety and environmental assessment of the PivotBuoy system. The Failure Mode, Effects and Criticality Analysis (FMECA) process has been the primary vehicle for this assessment. In addition, the HAZard IDentification (HAZID) process has been used to assess risk for transportation and installation activities.

During the period since the initial issue of the FMECA register [Ref 1], significant effort has been made to expand and to update the register to reflect the latest design status. More importantly, the findings of the FMECA process have continually been fed back into the design so that risks could be assessed. This iterative, interactive process has resulted in a design for the PivotBuoy system that is more robust and with lower risk. A significant number of risks identified through the FMECA process have been successfully “designed out” (i.e. eliminated), and most risks initially characterized as ‘High’ have been mitigated such that the residual risk is Low or Medium.

The FMECA register included in this report provides a snap-shot of the process as per mid-June 2020. Of the the 295 active entries in the register, 234 are considered closed (i.e. the actions identified to address the risk have been implemented). The remaining open entries (61) have actions that are ongoing or require implementation in a future phase. The FMECA register will remain a live document during the coming period, and open actions will be tracked to monitor progress towards closure.

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6 REFERENCES

[Ref 1] D6.1 "Identification of failure modes and initial reliability, health & safety and environmental assessment of the PivotBuoy system", September 2019.

[Ref 2] D2.3: "Detailed design review", March 2020

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7 LIST OF ABBREVIATIONS

ALARP – As Low As Reasonably Practicable

DDR – Detailed Design Reviews

FLS – Fatigue Limit State

FMECA – Failure Mode, Effects and Criticality

HAZID – HAZard Identification

HAZOP – Hazard & Operability Review

H&S – Health & Safety

LCOE – Levelized Cost Of Energy

RNA – Rotor Nacelle Adaptor

SCADA – Supervisory Control And Data Acquisition

SPM – Single Point Mooring

TLP – Tension Leg Platform

ULS – Ultimate Limit State

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APPENDIX A – FMECA Register

This Appendix has not been made publicly available due to IPR reasons.
In case third parties would like to request access to more detailed information, please get in contact with the project coordinator or through the project website:

Project Website: http://pivotbuoy.eu/contacts/

Project Coordinator: info@x1wind.com

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APPENDIX B – HAZID Guidewords

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HAZID Guideword	Examples of Potential Hazard Event Scenario
ACCESS	1. Difficulty to access during transport or installation 2. Potential for impeded access due to third party activities 3. Blocked evacuation routes 4. Work in confined spaces
BARRIERS	1. Absense of barrier 2. Reliability of barrier 3. Valve positioning error
COLLISION	1. Vessel positioning system failure
COMMUNICATION	1. Loss of communication
CONNECTIONS	1. Connection difficulty or failure because of ROV / Divers installation error 2. Connection difficulty or failure due to poor alignment or hydrodynamic forces 3. Complex connection, difficult installation or retrieval for the divers or ROV
CORROSION	1. Corrosion during storage / transport
DEBRIS / FOULING	1. Debris during transport → impact 2. Debris preventing flooding or venting
DESIGN LOADS	1. Excessive loads during lifting / installation 2. Excessive loads from temporary hose connections 3. Excessive loads from third party interaction
DIVING	1. Release of pressure 2. Sharp edges 3. Trapped air 4. Umbilical tangling or snagging points 5. Pinch points 6. Heavy components or activities requiring force (also absence of hold-fasts)
DROP / IMPACT	1. Impact loads 2. Exposure of personnel and equipment in the water
ELECTRICAL ISOLATION	1. Residual or stored energy
FLOWRATE	1. Insufficient flowrate 2. Excess flowrate
HOT WORK / IGNITION	1. Fire / explosion
INGRESS / FLOODING	1. Uncontrolled flooding
LEAK / RELEASE	1. Leak to environment 2. Contamination (air or water)

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HAZID Guideword	Examples of Potential Hazard Event Scenario
LIFTING / HANDLING	1. Dropped load 2. Impact 3. Loss of control 4. Lifting over personnel / equipment 5. Handling of heavy objects by persons
LOSS OF BUOYANCY	1. Unplanned flooding of compartments
MOVEMENT – UNPLANNED	1. Shifting load on deck 2. Loss of stability 3. Load imbalance
POSITION	1. Vessel positioning error 2. Survey error 3. Incorrect placement of equipment onto seabed
PRESSURE	1. Over pressure 2. Trapped pressure 3. Under-pressure → collapse
SPEED	1. Excessive speed 2. Insufficient speed
STABILITY	1. Inability to maintain stability during transport / installation (lifting) 2. Unstable foundation due to soil conditions 3. Instability due to connection failure
STUCK	1. Stuck rigging 2. Stuck valve
TEMPERATURE	1. Expansion / contraction of structural elements 2. Pressure fluctuations
THIRD PARTY	1. Interaction with others
TOLERANCES	1. Too tight 2. Too loose
VESSEL	1. Collision with structure or other vessels 2. Extreme motions
WEATHER	1. Harsh weather conditions during installation 2. Complex installation or operation requires strict weather limitations 3. Loss of visibility
WORKING ENVIRONMENT	1. High noise levels 2. Insufficient ventilation 3. Work at heights 4. Work over open sea 5. Seasickness

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APPENDIX C – HAZID Register

This Appendix has not been made publicly available due to IPR reasons.
In case third parties would like to request access to more detailed information, please get in contact with the project coordinator or through the project website:

Project Website: http://pivotbuoy.eu/contacts/

Project Coordinator: info@x1wind.com

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