Installation of the SABELLA turbine - D10

FEEDBACK FOR FUTURE INSTALLATIONS

DELIVERABLE WP T 1.5.3 TIGER PROJECT
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Document history

Version	Date	Author	Comments
1.0	02/02/2023	**MHE - *Robin Falcone***	Confidential version
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This report was written by PP05 MHE56, hereafter MHE, a partner in the TIGER project.

Introduction

The TIGER projects

The TIGER project aims to accelerate tidal energy growth in the Channel region while providing significant economic benefits for coastal communities. It responds to the need to reinvigorate the tidal energy sector in France and the UK, whose development has slowed due to a lack of pace in commissioning projects, because partnerships between SMEs are not sufficiently developed, and because tidal energy has not been presented to the public to gain political support for the sector, which discourages private investment overall.

This project aims to address these challenges by developing, testing, and demonstrating new technologies in and around the Channel area through cross-border partnerships. The feedback from this unique experiment will help build a stronger, more cost-effective case for tidal power as part of the energy mix in the UK and France. The project brings together organisations specialising in the sector, SMEs, technology developers, and academic experts to form cross-border teams to accelerate the sector's development faster and more effectively, thanks to INTERREG support. The project's partner turbine developers, supported by academic and research organisations, are working together, creating a new supply network in the UK and France. This will provide new designs for more efficient and cheaper turbines.

Project partners

University of Exeter

The University of Exeter is ranked in the top 150 universities in the Times Higher Education World University Rankings. It is involved in over 100 European projects. It has over 20 years of experience in wave analysis, resource modelling, marine hydrodynamics, moorings, testing, reliability engineering, offshore installation, operation, and maintenance

ORE Catapult

The UK Government funds the Offshore Renewable Energy Catapult as the UK's flagship technology, innovation and research centre for wind, wave, and tidal energy. It is involved in large-scale collaborative R&D projects and commercially and publicly funded innovation projects. It operates open-access test facilities for powertrain reliability, blade fatigue, component failure assessment and autonomous systems for remote data collection and asset inspection.

Cambrian Offshore

Cambrian Offshore was formed in 2018 to deliver the Ramsey Sound Regeneration Project. This will see the deployment of a tidal turbine installation comprising a grid-connected subsea turbine, substation, and associated infrastructure.

University of Plymouth

The University of Plymouth is a public university based in Plymouth, England, where the main campus is located. Still, the university has affiliated campuses and colleges throughout the Southwest of England.

Bretagne Développement Innovation (BDI)

Bretagne Développement Innovation is Brittany's regional innovation and economic development agency, with 50 staff.

Électricité de France (EDF)

EDF is a major French utility with a long history of involvement in renewable energy through its subsidiary EDF-RE. EDF has obtained concessions and operates the majority of hydroelectric power stations in France. This experience of energy extracted from water led to hydropower interest at an early stage.

University of Southern Brittany (UBS)

UBS is a public scientific, cultural, and professional institution.

Morbihan Hydro Energies SAS

Morbihan was set up to exploit the potential of the energy resources available in the marine environment. It has extensive knowledge of the region, its stakeholders, energy consumption patterns and distribution, and experience in turbine design, production, and installation.

HydroQuest

HydroQuest, based in Grenoble (French Alps), was founded in 2010 and has developed a complete range of hydrokinetic turbines capable of generating electricity from rivers, estuaries, and tidal currents.

Normandie Hydroliennes

Normandie Hydroliennes brings together the partners SIMEC Atlantis Energy (SAE), AD Normandie and EFINOR. SAE supplies turbines and expertise to Europe's largest tidal turbine site, Meygen, in Scotland. ADN is the regional economic development agency for Normandy. And EFINOR, based in Cherbourg, is a metallurgy and design company combining three business units - engineering, manufacturing, and support.

University of Caen Normandy

The University of Caen Normandy's numerous research units specialise in marine and coastal sciences. Historically focused on the sea, it has acquired internationally recognised knowledge and expertise in this field.

University of Le Havre Normandie

The Laboratoire des Ondes et Milieux Complexes (LOMC) is a joint research unit with the Centre National de la Recherche Scientifique (CNRS) and the Université Le Havre Normandie. It has expertise in experimental and numerical methods. The marine hydrodynamics group has been focusing on tidal energy since 2008 and is renowned for its collaboration with IFREMER on the study of tidal energy. The non-destructive testing group has expertise in testing the health of metal and composite structures using ultrasound

European Marine Energy Centre (EMEC)

EMEC is the world's leading test, demonstration and verification centre for offshore wave and tidal energy technologies. EMEC has hosted more marine energy devices than any other site worldwide.

Minesto

Minesto is a turbine developer with a unique, patented solution for generating electricity from tidal currents. Minesto is active at several sites worldwide, in Northern Ireland, Wales, the Faroe Islands and Taiwan, and has over 5 years of experience testing and installing power plants in various locations.

Orbital Marine Power

Orbital Marine Power has been recognised as the pioneer of floating tidal turbines since the company was founded in 2002 Orkney, Scotland. Orbital has maintained and enhanced this position by developing the world's most advanced knowledge and engineering technology in floating tidal turbines.

SEENEOH

SEENEOH brings together the different areas of expertise needed to test tidal turbine technologies in a real environment. Drawing on the know-how acquired at its estuary test site in Bordeaux, SEENEOH assists EDF in managing and operating the Paimpol-Bréhat site.

University of Manchester

The University of Manchester brings several areas of expertise in fundamental research, including hydrodynamic analysis methods applicable to tidal and wind turbines in turbulence and waves, integrated condition monitoring techniques and innovative manufacturing methods, including for composite structures such as turbine blades.

QED Naval

QED Naval is a technology developer specialising in the marine renewable energy sector. Their tidal platform, Subhub, is a fully integrated system that supports tidal turbines and everything they need to generate tidal energy, including the electrical infrastructure.

European Regional Development Fund (ERDF)

Interreg VA France (Channel) England is an EU programme that funds projects that benefit the Channel area in the south of the UK and the north of France using ERDF funds. The programme provides funding for projects where partners work together to solve common challenges in the Channel area.

What is tidal energy?

There are two main types of current: ocean currents (such as the Gulf Stream), which are influenced by differences in the temperature and salinity of the water mass (deep currents) and global winds (surface currents), and tidal currents, which are linked to the effects of the gravitational forces exerted by the Moon and the Sun, and to the Earth's rotation. This tidal effect is important in places where rivers or coasts meet. Seabed topography generally accelerates tidal currents, especially around capes, in straits between islands, and in shallow water.

These are the areas of greatest interest to the industry. They offer a potential electricity supply close to the coast because of their proximity to energy transmission networks.

Semi-diurnal tides characterise Europe with 4 phases: high tide, ebb tide, low tide, and flood tide. This cycle lasts 12 hours and 25 minutes and is repeated twice daily. The back-and-forth movement of these water bodies creates ebb and flow currents. The current spreading phases correspond to the current reversal and are current-free. During slack water phases, electricity production is zero because it depends on the cubic amplitude of the current speed.

Purpose of the document

Several challenges need to be met to encourage the development of the tidal energy sector. Among these, maritime operations, particularly the deployment of turbines, represent a major industry development area.

This document contains recommendations based on feedback from the SABELLA D10 tidal turbine deployment in the Fromveur Passage in April 2022. It is with a view to derisking MHE operations in the Gulf of Morbihan.

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Part 1: Background to the D10 project

1. The D10 project: a historic first

The D10 project, led by the Quimper-based company SABELLA SA, was the winner of a call for expressions of interest from ADEME (the French Environment and Energy Management Agency) for a "Marine Energy Demonstrator" project and has received support from the Investing in the Future Programme. This nomination led to the first immersion in June 2015, making D10 the first tidal turbine injected into the French grid.

The D10 project was succeeded by the ICE - *Intelligent Community Energy* - project, supported by Bretagne Développement Innovation, which enabled a new trial period after the demonstrator was refurbished.

2. The 2022 test campaign: a strategic validation milestone for the deployment of two D08s in the Gulf of Morbihan

2.1. Issues

Furthermore, the D10 project's specific objectives, including the certification of the demonstrator's power curve, provided MHE - Morbihan Hydro Énergies with a huge opportunity. This test campaign made it possible to study and validate the technical and operational choices (or constraints) impacting the smooth running of MHE's scope within the framework of the Tiger project. These elements are detailed in the following sections.

2.2. Technological and functional choices

MHE must control the following elements as part of the project:

- machine control strategy.
- network injection management, in line with the requirements of the network operator.

This document will not discuss these elements as they are the subject of a separate deliverable.

2.3. Operational choices

Installation and commissioning of the tidal turbines and their associated equipment are MHE's responsibilities. As a result, the deployment and 2022 test campaign for the D10 demonstrator has enabled MHE to compare the following elements:

- maritime operation scenarios (planning, choice of equipment, etc.).
- vessel performance.
- the relevance of Wet-Mate connectors for maritime operations.
- the commissioning procedure.

The deliverable mentioned above will also detail feedback specific to the commissioning procedure.

Second part: comparison between Project Tiger and Project D10

1. Introduction

It is necessary to take a step back from these two projects to identify their similarities and differences to understand better the benefits MHE can derive from the maritime operation conducted by SABELLA in April 2022. In particular, this exercise will allow us to identify the technical and operational limitations of replicability between the D10 and TIGER projects.

2. Comparison of sites: Fromveur and Golfe du Morbihan

2.1. Weather and oceanographic conditions

The Fromveur Passage and the Mare's Current are two sites with great tidal potential. However, they are very different in terms of weather and oceanographic conditions. The table below summarises the characteristic values for swell, water speed, and bathymetry to be considered for marine operations.

/	Courant de la jument	Fromveur
Decennial swell	Hs = 0.96 m ; Tp = 18.56 s	Hs = 8.16 m ; Tp = 9.74 s
Decennial wind seas	Hs = 2.15 m ; Tp = 5.48 s	[]
Duration of the reversal for a coefficient 88 *(Water speed less than 1 m/s)*	50 min	1h10
Duration of the reversal for a coefficient 24 *(Water speed less than 1 m/s)*	2h50	10h30
Maximum water speeds *(averaged over 10 minutes)*	3,62 m/s	4,45 m/s
Bathymetry *(MSL)*	25 m	57 m

Table 1: Comparison of meteorological conditions in the Courant de Jument and the Fromveur current

MHE can benefit from the maritime operation conducted by SABELLA in April 2022 by taking a step back from these two projects to identify their differences and similarities. In particular, this exercise will enable us to identify the limits to the replicability of the D10 project to the TIGER project regarding technical and operational aspects.

By contrast, the Courant de la Jument is very well protected from the swell. This has several advantages, including :

- Reduce the risks due to swell during the operation.
- Increase the number of operational windows.

This feature will enable maritime operations in winter when there is less activity in the Gulf of Morbihan, and the offshore market is more attractive.

D10 maritime operations have been adversely affected by the swell on several occasions. The spring 2022 operation is a case in point.

Bathymetry also plays an important role in the planning of maritime operations. The greater the bathymetry, the longer the time required to lower and raise the packages. Therefore, the time required for the same operation is greater in the Fromveur than in the Courant de jument.

However, while the Fromveur Passage is complex because of its depth, the current in the pond is advantageous because of its bathymetry.

2.2. Topographical conditions

Compared with the Fromveur, the Gulf of Morbihan site is cramped. The vessels will therefore have to be perfectly positioned and manoeuvred. Therefore, the operation in April 2022 enabled MHE to gain experience that will enable it to conduct future operations as part of the Tiger project. This is as effective as possible. The figure below shows two satellite views that clearly show the difference in space available for operation.

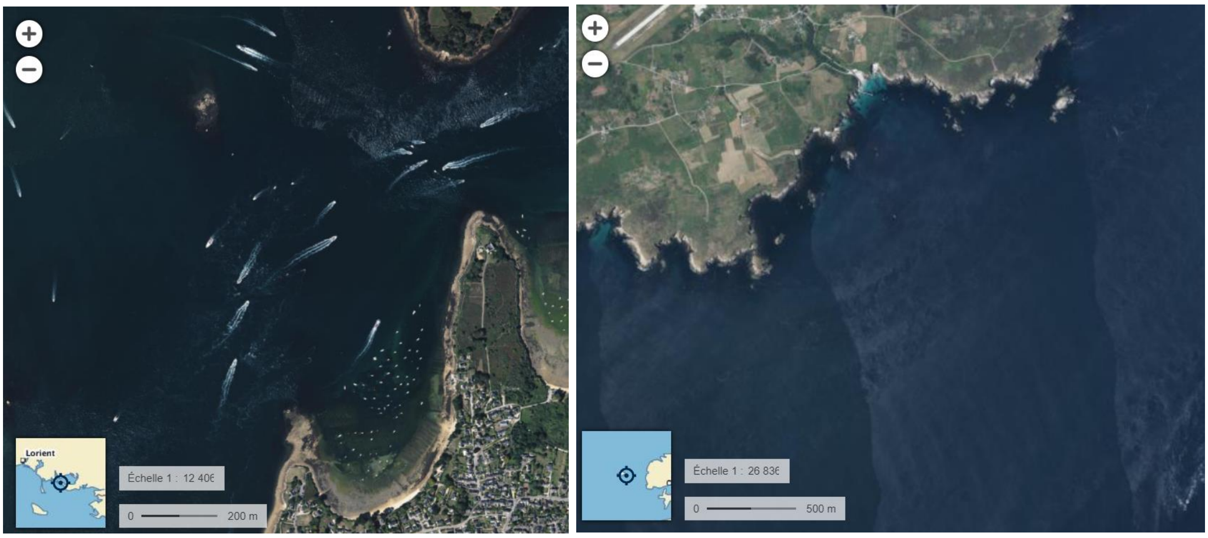


Figure 1: satellite view of the Courant de jument (left) and the Fromveur current (right)

As described throughout this document, the dynamic positioning of ships in very restricted areas is clearly possible.

3. Operational comparison

3.1. Nautical means

Except for the cable and remote caisson operations, which will be carried out by Multicats, the Normand Superior has been the vessel targeted by MHE for the deployment of the D08s since the design phase. This vessel was previously used (then named Far Superior) on the D10 project and will be reused in April 2022. Therefore, the study of vessel performance is immediately applicable to MHE deployment procedures.

3.2. Landing

Landing zones are generally located directly along the cable laying axis and near the foreshore. As part of the Tiger project, the landfall presents several constraints:

- Poor access to handling equipment.
- Splicing will be carried out between the terrestrial and submarine cables.
- Cable needs to be repositioned.

All these constraints are also present at the Arlan site, where the export cable for the D10 tidal turbine was landed during April 2022 operation. Therefore, the feedback from this operation will greatly benefit MHE in deploying the cables for the TIGER project.

4. Technology comparison

TIGER's D08s and the D10 differ primarily in their use of Wetmate connectivity, which eliminates several constraints. This document recounts the feedback from this operation, which supports this technological choice.

Part Two: Feedback on the April 2022 transaction

1. Description of the operation

1.1. The Fromveur site

The SABELLA - D10 tidal turbine is immersed in the Fromveur Passage between the Molène archipelago and the island of Ushant north of the Iroise Sea. The cable landing is located on Arlan Beach on Ushant Island. The figure below shows the turbine location and the cable route.

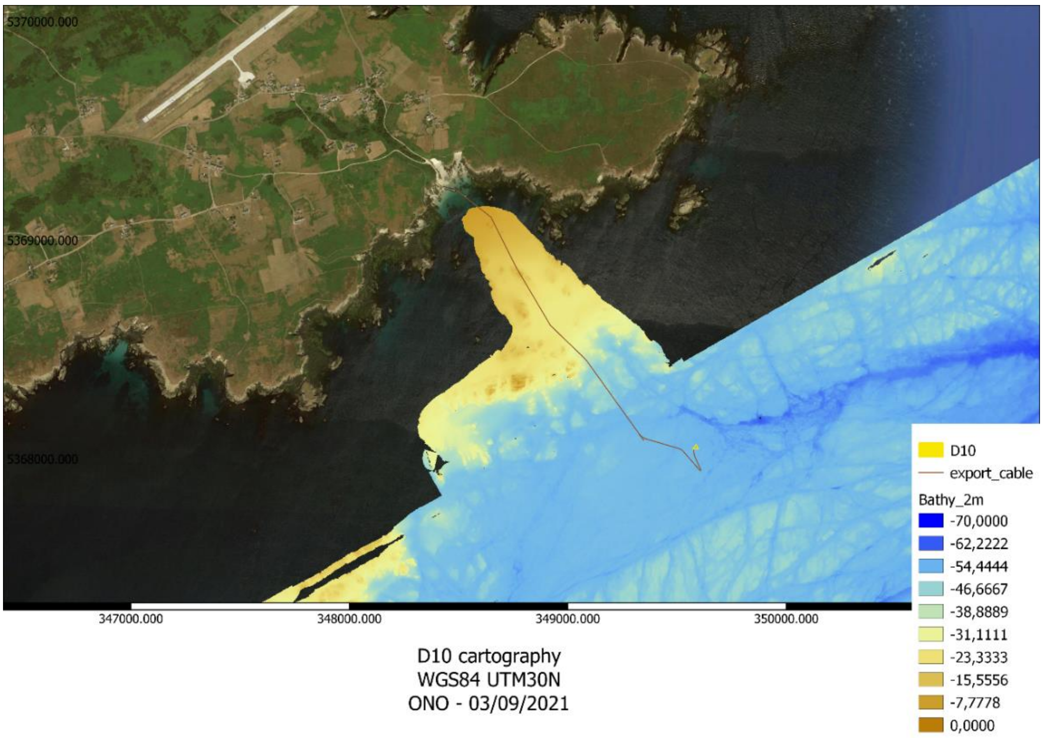


Figure 2: Satellite view and bathymetric map of the Fromveur Passage and the location of the D10 tidal turbine

The weather and sea conditions at the location where the tidal turbine is submerged are as follows:

Features	Values
Bathymetric level (LAT)	*50,4 m*
Maximum water speed (10 min)	*3.62 m/s*
Float/Milling offset	*14,4°*
Ten-year swell	*Hs = 8.14m / Tp = 9.12s*
Slack time (V<1m/s) coefficient 24	*10h30*
Slack time (V<1m/s) coefficient 88	*1h10*

Table 2: characteristics of the D10 disposal site

1.2. Weather conditions

As the operation approached, a strong low-pressure system was forecast. The weather conditions exceeded the operational limits, so it was necessary to review the planning of the operation.

The figures below show the wind and swell conditions from the latest weather report dated 04/04/2022.

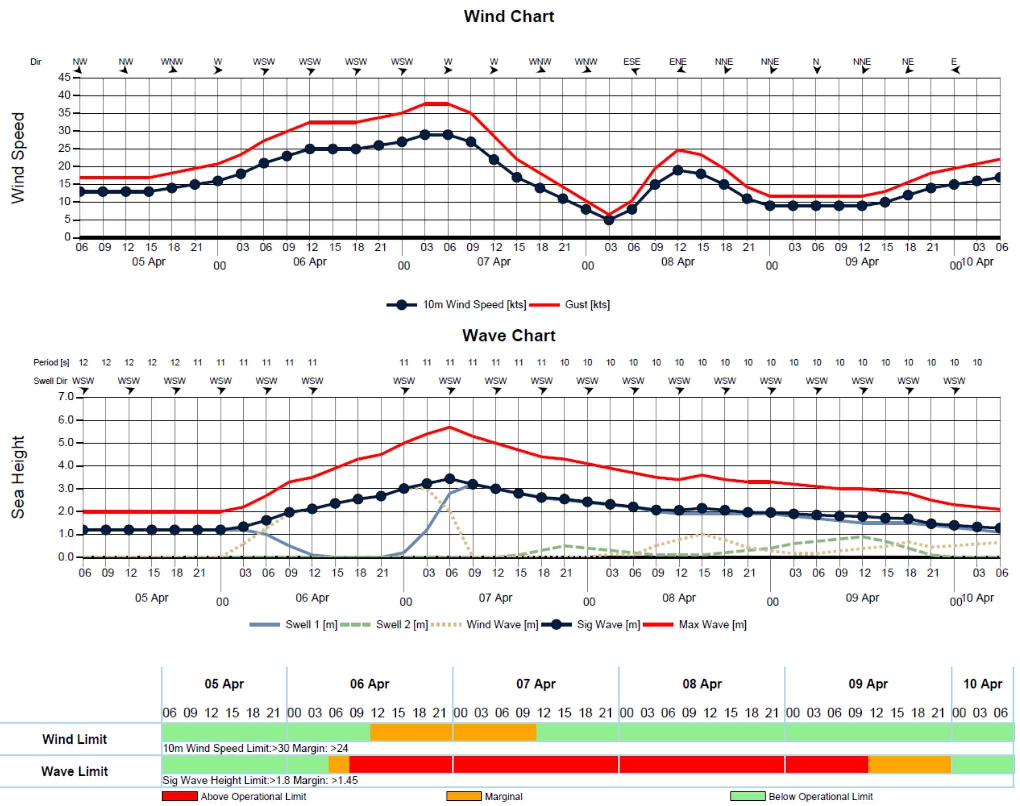


Figure 3: weather reports before the operation

1.3. The operation

The April 2022 operation was the most complex of the D10 project, and the following table describes the tasks to be carried out on the dead water.

ID	Description
Task 1	*Mobilisation at the port of Brest*
Task 2	*Transit on site* *DP* *As Found survey*
Task 3	*Landing the cable*
Task 4	*Laying the cable*
Task 5	*Grounding the cable*
Task 6	*Fitting the turbine*
Task 8	*Connection*
Task 9	*ADCP SW relief*
Task 10	*Fitting of SW and NE ADCP*
Task 11	*Demobilisation*

Table 3: list of "macro" tasks to be carried out during the spring 2022 operation

Given the conditions, it was decided to optimise the time available at the start of the operational window. To do this, the operation was split into three parts, the first consisting of a reduced mobilisation to deploy only the tidal turbine, the second being the demobilisation of the tidal turbine cradle and the mobilisation of the equipment needed to lay the cable, and the last, the completion of the remaining tasks at sea.

Although forced, this new planning has had many advantages, including :

- Limiting the risks to the tidal turbine deployment by exploiting a low swell window.
- Optimising weather standby slots with dockside activities (mobilisation and demobilisation).
- Managing teams.
- Reducing bridge clutter.

This last point is significant feedback for MHE as part of the D08 deployment for the Tiger project. Although the ship is high-performance, it has very small deck space. It would have taken up too much space if the operation had been carried out in one go, resulting in risks for people and operational complications.

1.4. Parcels

The characteristics of the cable drum are described below.

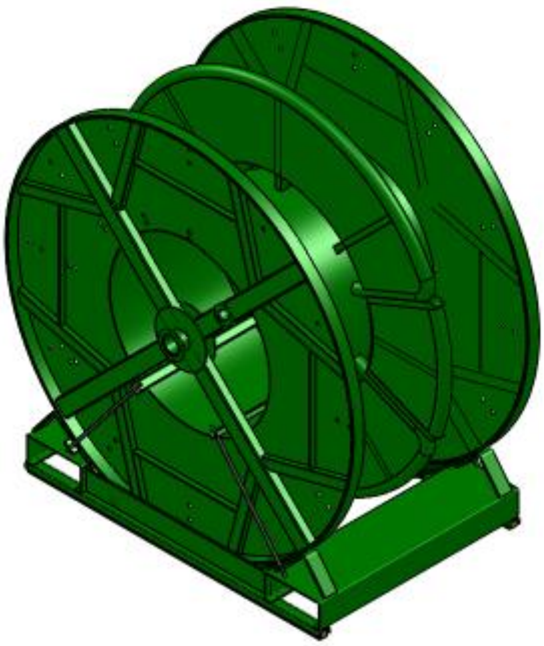


Figure 4: cable drum

The characteristics of the turbine are shown in the figure below.

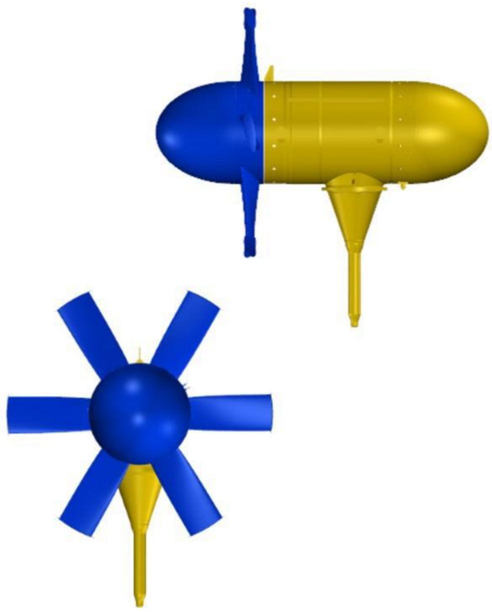


Figure 5: characteristics of the d10 nacelle

The characteristics of the D10 cradle are shown below.

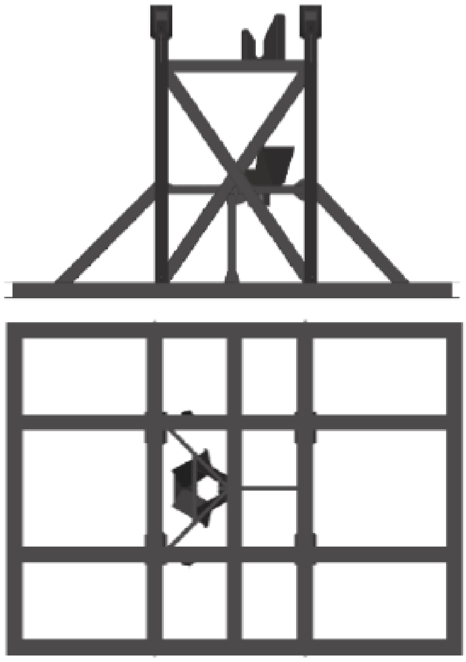


Figure 6: characteristics of the D10 crib

The features of the *LARS - Launch And Recovery System* are presented below.

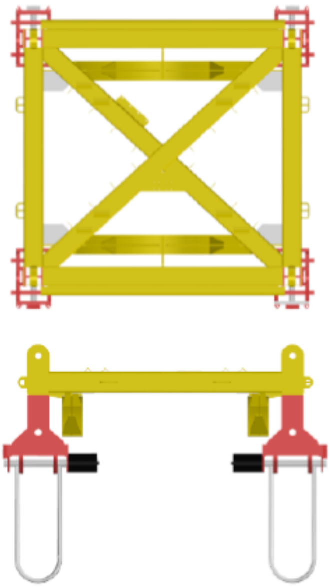


Figure 7: characteristics of the D10 LARS

The table below details the largest parcels in the D10 and Tiger projects.

Components Height (m) Width (m) Length (m) Mass (t)

Composants	Hauteur [m]	Largeur [m]	Longueur [m]	Masse [t]
D10 - Nacelle	*12*	*10*	*12*	*107*
D10 - Ber	*6,7*	*7,5*	*10,4*	*25*
D08 - Embase	*8*	*12*	*13*	*40*
D08 -Nacelle	*8*	*8*	*10*	*50*
D08 - Ber	*3*	*4,8*	*6*	*25*

Table 4: Comparative table of packages for the D10 project and the TIGER project

1.5. Operational resources

The vessel selected for the operation was the Normand Superior from the Ocean Infitiny - Solstad Offshore fleet. By coincidence, this was also the vessel MHE used as a reference for deploying the D08 bases and nacelles. This was at the beginning of the Tiger project's design phase. As a result of this operation, MHE could evaluate ship performance in situ.

Below are the characteristics of this vessel.

Vessel specs

Built	2017
Design	Vard 3 17
Flag	NIS
Accommodation	85 Persons
LOA	98,1m
Cargo Deck Area	875m²
ROV	Yes
Yard	Vard Vung Tau
Main Class	+1A1, SF, DK(+), COMF-V(3)C(3), SPS, CLEAN DESIGN, DYNPOS-AUTR, NAUT-AW, BIS, SPS
Dynamic Positioning	DP 2 from Kongsberg
Classification Society	DNV GL
Helideck	Diameter 26,1m, Sikorsky 92 - 15 T
Draft (max)	6,6m + 0m Skeg/Nozzle
Deck Cargo Capacity	1800mt (CoG 1,0m above main deck)
Deck Strength	Free area 10 T m2 / 15 T m/2 aft of FR 41 mt/m²
Deadweight	4200mt (d=6,6m)
Main Crane	1 x SWL 150mt@ 15m - Single fall - AHC

Figure 8: Characteristics of Normand Superior

The equipment selected to unwind the export cable is described below.

Figure 9: photos of the equipment used to unwind the export cable

SPECIFICATIONS

Line pull	15Te
Maximum lay speed	970m/hour
Product capacity	50mm to 430mm diameter
Track grip force	52Te (22Te/m)
Track contact length	2.35m
Operating modes	Manual (Haul in/pay out - 15Te) Render (Holdback 1Te - 15Te) Constant tension (Haul in 2Te - 15Te)
Instrumentation	Line distance, line tension, line speed, grip pressure
Hydraulic supply	160 l/min / 240 bar maximum
Weight	7.8Te
Dimensions	L: 4.60m W: 2.23m H: 1.65m
Control	Local and remote in control cabin

SPECIFICATIONS

Traversing force	1.4Te @ 210 bar
Weight	2Te
Overall dimensions	L: 7.4m W: 1.44m H: 2.5m

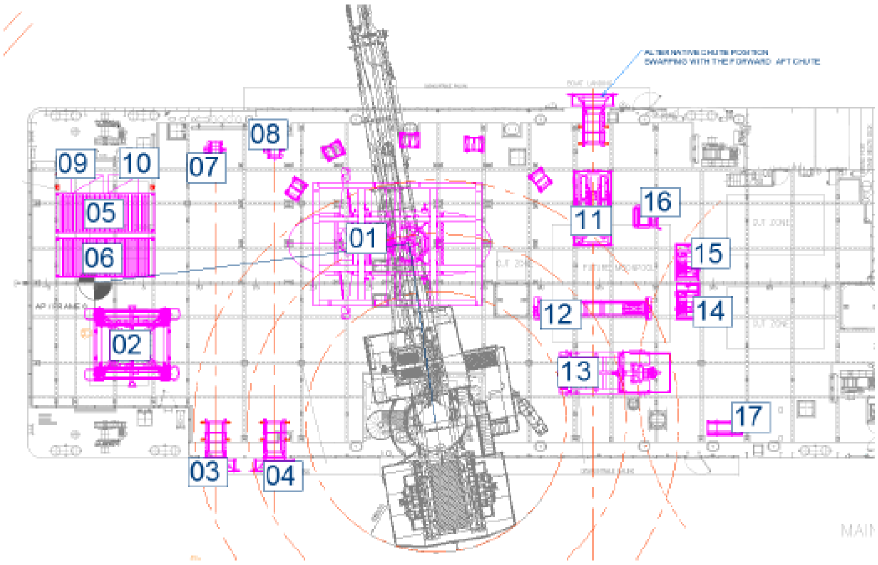
Figure 10: Characteristics of the equipment used to unwind the export cable

Except for two points, this equipment proved to be suitable:

- The cable often came out of the *tensioner* grooves for no apparent reason, so the laying speed had to be reduced.
- The unwinder shaft on which the reel rests bent under the reel's weight, and a new shaft had to be installed.

The boat deck layout is shown in the figure below. We can see that the space is very dense. Splitting the operation into two phases freed up the deck and made the work more comfortable. Cable handling requires a lot of space, and this type of handling must occur in both phases:

- Landing the export cable.
- Management of the slip road (130 metres) when the gondola is submerged.



ITEM NO.	ITEM DESCRIPTION	WEIGHT (te)
1	TURBINE & BERTH	135
2	TURBINE LARS & BERTH	15
3	AFT CHUTE	6
4	FWD CUTE	6
5	MACARTNEY CONTAINER	12
6	RIGGING CONTAINER	12
7	AFT TUGGER WINCH	1.02
8	FWD TUGGER WINCH	1.02
9	AFT TUGGER WINCH HPU	1.3
10	FWD TUGGER WINCH HPU	1.3
11	CABLE TENSIONER	7.8
12	CABLE LEVEL WINDER	1.89
13	CABLE REEL & DRUM(CABLE)	38
14	REEL DRIVE HPU	1.36
15	TENSIONER HPU	1.36
16	TENSIONER CONTROL CABIN	1.1
17	TOOLBOX	2
18	ROLLER BOX 1	0.27
19	ROLLER BOX 2	0.27
20	ROLLER BOX3	0.27
21	ROLLER BOX 4	0.27
22	ROLLER BOX 5	0.27

Figure 11: layout of the boat deck

Two ROVs were simultaneously chartered as the vessel, equipped with various tools (camera, pliers, knife, etc.).

2. Fitting the turbine

2.1. Course

The turbine installation operation is divided into several stages:

- Lifting the turbine, which involves removing the turbine from its cradle while at the same time following the cable.
- Overflowing the turbine, i.e., rotating the turbine around the crane axis and then lowering it to the surface to gradually fill the bulbs.

- Lowering the turbine to the baseplate.
- Embedding the turbine in the baseplate.
- Laying the cable brace.

2.2. Operational constraints

The turbine installation is an operation sensitive to swell conditions, so it was carried out on 05/04 before the low pressure arrived. The conditions were nevertheless complex, as there was almost a metre of significant height (the limit for this operation), and the coefficients were still 79-73.

Swell has a major impact on lifting operations before immersion since it causes the turbine to sway once it leaves its cradle.

The high coefficients impact the time available for operation, as the slack water is shorter. This is in particular because ROVs can only be submerged when water speeds are below 2 knots.

2.3. Lifting and overflow

The lifting and overtopping of D10 with the Normand Superior have enabled MHE to validate the vessel's ability to deploy to the Tiger project base. As the Gulf of Morbihan is very well protected from swell and wind, the risks of rocking will be extremely reduced compared with the D10 project

Figure 12: Overflow of turbine D10

2.4. Turbine lowering

Once the bulbs were filled, it took almost 20 minutes to lower the turbine. The nacelle's centring finger was then centred with the guide cone of the baseplate.

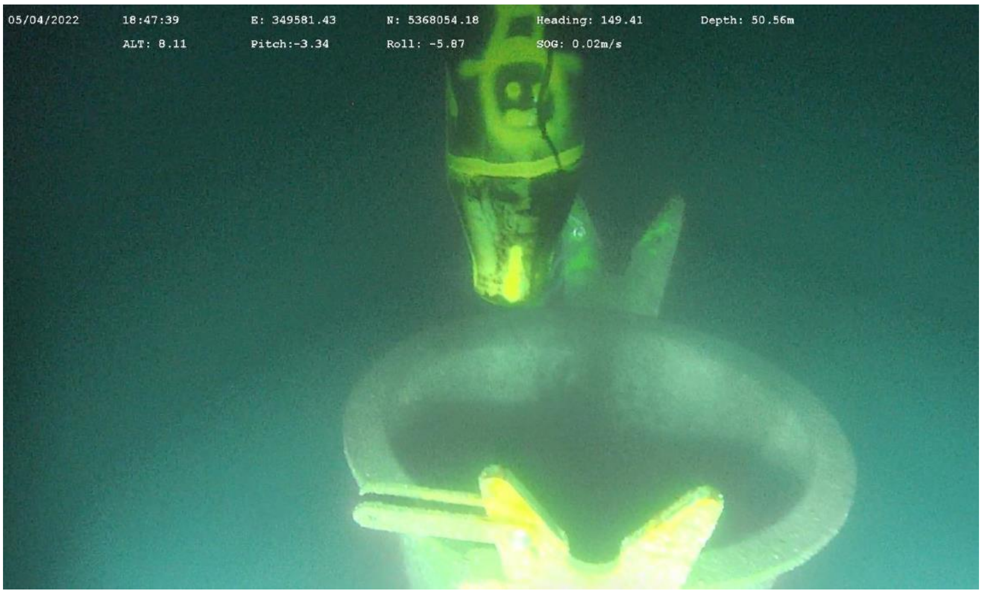


Figure 13: The nacelle pin approaches the base cone

At this point, the crane enters *Active Heave Compensation (AHC)* mode. The descent is slow, but the crane compensates for the heave caused by the swell during the embedding phase.

2.5. Turbine mounting

This operation must succeed by engaging the finger in the cone. As this operation is generally carried out in slack water, the vessel's dynamic positioning performance, in terms of correction, has little impact on the success of this phase. On the other hand, the vessel's displacement accuracy is significant since the vessel manages the horizontal plane's alignment. The Normand Superior exceeded expectations in this respect.

Swelling can influence the pin's horizontal movement. The ease of this operation depends, among others, on the ratio between the free surface of the base cone and the solid surface of the nacelle centring finger. The table below compares these dimensions for D08 and D10.

/	Centring finger [mm]	Centring cone [mm]	Area ratio [-]
D10	457	2054	0,049503
D08	320	1466	0,047646611

Table 5: Nacelle mounting system in the baseplate

This operation has shown that the proportions of this guidance system on the D10 demonstrator are satisfactory. In the Gulf of Morbihan, the swell is less pronounced. MHE believes that this operation will not pose difficulties for the D08s.

Once the nacelle is engaged in the baseplate, and to finalise the installation, the machine must be rotated to align the anti-rotation lugs correctly. As the turbine has a large surface area facing the incident flow, the slightest speed of residual water causes it to rotate. This has been partially corrected by crane winches (tuggers) connected to the LARS' ends. However, the depth of the Fromveur was such that the angle between the crane and the LARS was too small to manage the alignment using these winches. The ship's axis, therefore, had to be reconfigured by a few degrees to obtain the correct alignment.

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Figure 14: Photograph illustrating the difficulties encountered when fitting the nacelle into the base.

This alignment was all the more difficult to manage as it had to be carried out simultaneously on both sides of the turbine. The ROV only was able to see one of them. This second phase took 28 minutes. Significant time savings could be made at this stage by including a guidance system at the design stage. This guidance system manages the nacelle's orientation as it is fitted into the base.

2.6. Installing the ramp

Once the rig has been installed, the LARS is released and returned to the deck. The cable sling can then be engaged in the cable guides and deposited on the seabed as far as the Drymate connector; this last stage can be carried out without an ROV by moving the vessel.

The water velocities became too high again, and the ROVs had to be repatriated before the sling could be correctly positioned in the cable guides. The sling was therefore kept in place until the next slack of water, which was entirely dedicated to finishing this operation.

Keeping the cable on the bridge between two slabs always presents a risk. If the dynamic positioning system fails, the cable must be abandoned quickly. In the most severe case, the cable is cut with a thermal cutter, causing irreversible damage.

2.7. Conclusion

Although the operational window was limited due to high coefficients, the operation performed well. Using a better guidance system, the need for ROVs and dry-mate technology due to the ramp installation resulted in a significant loss of time and the need to operate in two stages. As a result:

- Proven: an economic loss.
- Potential: risk of cutting the cable in case of a DP fault between the two slabs (not proven this time).

MHE conducted a comparative analysis through this operation to determine the turnaround time required to deploy a D08. This analysis is based on:

- A comparison of reversal times, by coefficient, between the Fromveur and the passage of the mare.
- Descent time is required for D10 and D08.
- Potential time savings thanks to the D08 alignment system.
- Potential time savings thanks to the Wet-mate system.
- Estimation of the increase in the operational window using no ROV.

Based on this information, the D08s can be deployed by a vessel identical to the Normand Superior up to a tidal coefficient of 75.

3. Laying the cable

3.1. Preparing the cable

The new export cable was pre-rolled onto the reel, with the end of the cable on the reel drum placed in a separate compartment on the reel to remain accessible. This way, the dry-mate connector could be fitted to the cable and secured to the reel before operation. This procedure will be repeated for installing D08 cables by MHE (fitted with Wet-Mate interfaces in this case), as it reduces the risks and costs of operation.

This choice does, however, entail several minor constraints to be considered, including :

- Increased clearance between the pallet of the cable reel and its axle (the connector flange protruding beyond the external diameter of the reel).
- Adding weights to the reel to balance it.

In the future, the free end of a cable stored on a reel will have to be kept taut by a hoist. Over the years, the cable has become loose around the reel axis. In a more serious case, it might have been necessary to unwind the entire cable and rewind it. As part of the TIGER project, MHE will require evidence that the cable has been properly stored before accepting responsibility for installation. Tiger cables are shorter, have less grip, and are more susceptible to loosening.

This end has been fitted with a permanent abandonment head to protect and pull the cable during landing. In the future, lighter temporary abandonment heads can be used for this type of operation.

Figure 15: (left and top right) photos of the new export cable drum with both ends accessible and the dry-mate connector fitted beforehand, (bottom right) the abandonment head.

3.2. Landing the cable

Generally, the landing chambers or delivery stations are located near the landing site to limit cable handling and damage. This wasn't possible in the D10 project since the new and old cables would have to cross a dike, head up a rock face, and then be connected in a trench.

Controlling cable lengths throughout the operation is a sine qua non for success.

Figure 16 shows a schematic diagram of this operation.

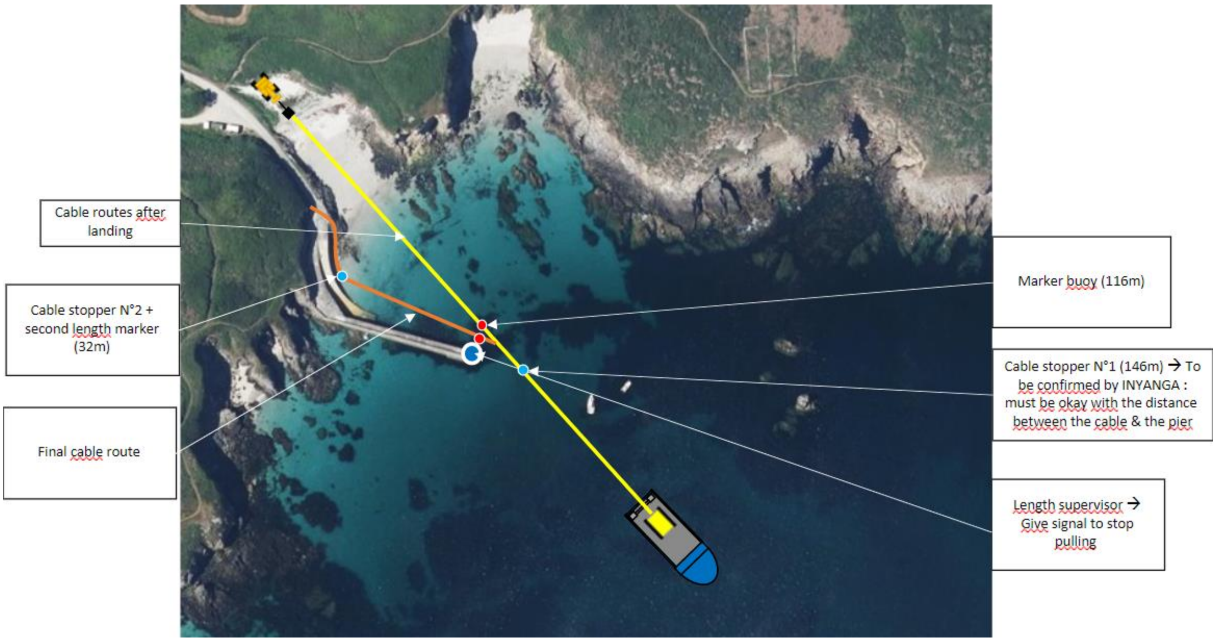

Figure 16 : schematic diagram of the operation, with the initial position of the cable in yellow and its final position in orange.

The procedure implemented by the SABELLA teams breaks down as follows:

- *Stage 1 - Landing a hauling rope*: brought ashore using a support boat.

Figure 17: Landing of the rope

- *Step 2 - Landing the export cable*.

A pulley block attached to a mini-excavator stationed on the beach releases the cable's pulling axis, which construction equipment pulls. A load cell was placed on the pulling machine to control the pulling force. The cable is kept afloat by buoys attached from the ship. The following figures show these devices.

Figure 18: cable landing device

Figure 19: Positioning the buoys from the ship

Only two operators could install the buoys due to a lack of space between the tensioner and the waterfall.

The A4 buoys proved unreliable, some of them becoming unhooked, which delayed the operation and increased the cable friction and, therefore, the traction to be applied from land. For the Tiger project, MHE will be using SeaFlex Float buoys exclusively.

- *Step 3 - repositioning the cable.*

A buoy marks the length of the cable to be pulled along a predefined line. Once the buoy is aligned with a land marker, the cable is secured by a sledge and can be repositioned along the dyke and on the rocky outcrop (Figure 20). To do this, a pulley block was placed on the securing points of the wedge, enabling the site machinery to reposition the cable.

Figure 20 : repositioning the cable along the dyke and on the rock face

Once the cable is perfectly repositioned, the buoys can be removed using the support boat. The planning and laying of the cable can then begin.

3.3. Laying the cable

The connector company could proceed with the jointing once the terrestrial end of the cable was available in the trench. The cable could then be laid.

This operation required high precision before the connection could be made. As the turbine was already immersed and the available length of the ramp could not be modified, the final position of the dry mate connector had to be respected to within a few metres.

The vessel is offset upstream of the flow to control the cable position on the seabed effectively. This is done at a distance and depends on the water's speed. This repositioning is carried out in real-time throughout the operation. Finally, acoustic beacons positioned regularly monitor the actual cable path. This way, the actual cable position could be compared with its theoretical position. A longer or more direct cable route could be redefined if necessary.

This procedure, combined with the vessel's positioning capabilities, meant that the connector could be installed within two metres of the desired location over a total length of almost 1,800 metres.

Figure 21: bottom-mounted connector

The condition of the cable was assessed from earth throughout the operation. Optical monitoring and insulation measurements were carried out continuously to ensure the cable was watertight and intact.

3.4. Cable splicing

The splicing operation consists of linking all the strands of the old and new export cables. This type of operation can be desynchronised from maritime operations, but the aim was to test D10 while the ship was on site. This, therefore, required very effective coordination (particularly for the optical and electrical monitoring mentioned above) between the onshore and offshore teams and the mobilisation of all the SABELLA teams.

This connection could have been made at sea, but this would have meant waiting 36 hours before the cable could be laid, prolonging the operation.

3.5. Assessment of the operation

This complex operation is very similar to MHEs in the Gulf of Morbihan. The cable will have to go around an oyster farm, then up the beach to be spliced with a previously installed land cable. The availability of site machinery is also limited at the two sites, on Ushant, because of its island nature, and in the Gulf of Morbihan, for accessibility. This operation, therefore, represents major feedback for MHE and means that maritime operations for the Tiger project can be de-risked.

4. Connection

Once the cable has been laid, the brace and turbine can be connected. The two dry-mate connectors are then returned to the bridge, and the connection can begin. During this phase, continuous tests are carried out from land to ensure that the connection has been made correctly and that the tidal turbine is operating correctly.

Once the operation has been validated, the connectors can be immersed.

Figure 22: Immersion of connectors

This operation enabled MHE to confirm its choice of wet-mate technology for deploying the D08s. This operation requires almost 18 hours more with dry-mate technology. Moreover, the export cable and sling are on the boat's deck during peak currents. In the event of a DP loss, the connectors will be left open, or the cable will be severed, causing irreversible damage. This technology induces significant risk.

5. Fitting ADCP

The ADCPs were installed at the end of the operation. The IEC 62600-200 standard deployed the ADCPs. To avoid subsequent dives, the ADCP stations were fitted with compasses designed to be visible on ROV images. In this way, ADCP attitudes could be directly adjusted when deployed. This operation once again demonstrated the vessel's excellent performance.

MHE will reproduce this procedure as part of the Tiger project.

Figure 23: ADCP station fitted with an ROV compass

6. Review of Wetmate technology on the D08s

6.1. Alignment

The operation demonstrated that the vessel's positioning performance was sufficient. However, the guidance system design must make it as easy as possible to fit the nacelle into the base, particularly when using passive Wetmate technology. The design of this system must involve those responsible for the following work packages:

- Nacelle.
- Baseplate :
- Offshore operation.
- Connectors.

6.2. Effort management

During embedding, the crane's weight was monitored. This enabled MHE to challenge the compression assumptions for the Wet-Mate passive connection.

Logically, it was found that the AHC mode reduces accelerations and, therefore, the stresses applied to the connector system. This technology will be necessary for chartering the vessels responsible for installing the D08s.

6.3. Wet-Mate Vs Dry-Mate advantage

This operation confirmed the choice of a Wet Mate. While the major disadvantage of this technology is its investment cost, the advantages are numerous:

- Significant time savings during changeover and re-installation operations
- Limitation of operational risks concerning PD losses.
- Essential on large farms for managing cable routes.

7. Dynamic positioning performance

7.1. DP tests

The boat's positioning accuracy and the risk of failure of the dynamic positioning system are highly dependent on meteorological factors, in particular :

- Swell.
- Windy.
- Power.

During this operation, dynamic positioning tests were carried out on two occasions, the first when the vessel arrived on site and the second when it returned to the site at the end of the depression. These two tests proved complementary, as weather and ocean constraints differed. The table below summarises the conditions under which these tests were carried out.

Date	Swell	Wind	Water speed
05/04/2022	Hs = 1m Tp = 12s	10 knots	6.2 knots
08/04/2022	Hs = 3.5 m TP = 10.5 s	35 knots	3 knots

Table 6: Conditions under which the DP tests were carried out

7.1. Performance in heavy seas

On returning to the site, during the second part of the operation, the swell and wind conditions were still significant. Nevertheless, several operations were carried out, including preparing, slinging, and lifting an ADCP station.

The figure below shows the sea conditions and bridge anemometer readings (in knots) a few hours before the ADCP operation.

Figure 24: Weather conditions on return to the site

The figures below show the operations carried out on the ADCP in almost three metres of swell. The operation comprised the following stages:

- Cutting and removing an old sling.
- Pass two slings through the 40 mm diameter lifting rings.
- Hook the slings onto the crane hook.
- Repatriate the ADCP station to the bridge.

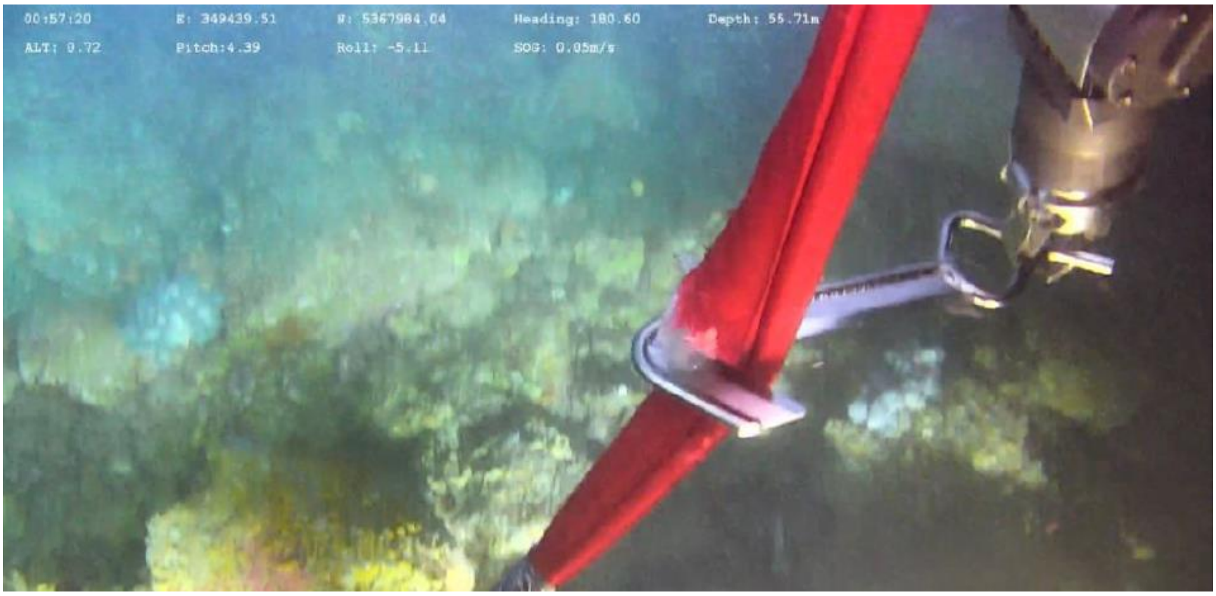

Figure 25: Cutting the old sling

Figure 26: Slinging the ADCP station

7.2. Balance sheet

All the tests and operations carried out by the Normand Superior have confirmed MHE's confidence in the ship's positioning performance and ability to carry out the maritime operations involved in the Tiger project. This is particularly true of the choice to integrate Wet Mate connectivity.

8. Summary of feedback from the operation

The following table summarises the feedback from this operation by phase.

Wetmate Connectors

Table 7: Summary table of techni

Operation phase	Procedure		Design		
[]	Positive points	Negative points	Positive points	Negative points	Possible Improvements
Lifting the turbine	- Operation successfully created	- - Highly dependent on swell conditions - - Complex and risky cable ramp management	- Dimensions and weight compatible with the vessel	- Drymate connection requiring a cable strap	- Wetmate connectors
Turbine lowering	- Operation successfully created	- Perfect synchronisation required between the handling teams on the bridge and the crane operator to keep the ramp tension-free	[]	- Drymate connection requiring a cable strap	- Wetmate connectors
Turbine mounting	- Vessel performance - Choosing a vessel equipped with AHC technology	- Visual on one side of the turbine only possible - Final alignment created by changing the axis of the vessel - Wasted time	- Guide cone and centring pin dimensions satisfactory	- The guidance system does not ensure the correct orientation of the turbine	- Guiding system for setting the turbine's axis of orientation during installation
Installing the ramp	- Operation successfully created	- - Creation carried out over two stages due to lack of time, with the strap held between the vessel and the turbine, resulting in potentially irreversible damage in the case of abandonment due to a DP failure. - - Time-consuming embedding of the sling in the cable guides.	- *Choice of type and number of bend restrictors*	- Presence of a ramp - Length of slip ramp excessive	-- Wetmate connectors
Preparing the cable	- - Connector assembled on the cable in advance of the phase - - Installation of a drop head on the terrestrial end	- Free cable on the reel, a hoist would have maintained the tension	[]	- Weight of the drop-out head	- Lighter temporary drop-head
Docking the cable	- - Return pulley to fix the pulling axis and free the pulling gear from this constraint - Use of a cable clamp to secure the cable once the correct length has been landed - - Length control - - Repositioning procedure adapted to site constraints	- - A4 buoys are not recommended for this type of operation - - Repositioning preferable at high tide to limit lifting constraints - - Limited space between the drop and the tensioner to install the buoys on the cable	- Lightweight cable	- Weight of the drop-out head	- - Lighter temporary abandonment head - - Seaflex Float buoy to be preferred - - AHTS vessel better suited to this operation
Cable installation	- - Positioning of the boat according to water speed (charts) perfectly created - - Installation of acoustic beacons to monitor the position of the cable in real time - Optical and electrical tests to monitor cable integrity	[]	[]	- Lightweight cable subject to high current velocity	- Choose a heavier cable
Splicing	- - Good coordination of shore and sea teams - - Enables the machine to be tested before the vessel leaves the site - - Onshore creation saves a significant amount of time over the maritime operation	[]	- Junction box design	[]	[]
ADCP Instalation	- Use of ROV compa and management of the final attitude during deployment with the ship	[]	[]	[]	[]

Table 7: Summary table of technical and operational feedback from the April 2022 operation

Conclusion

The report describes a tidal deployment. This information will benefit the local industry and the wider public. As a result, the industry will benefit from a better understanding of the issues at stake. This will improve the acceptability of this type of project. The operation carried out by the SABELLA team as part of the D10 project will validate many of the technical and operational choices essential to MHE as part of the TIGER project and the deployment of the two D08s.