Base Load Power Hub (BLPH)

ACCEPTANCE CRITERIA FOR OFFSHORE INSTALLATIONS

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1 INTRODUCTION

1.1 PROJECT OVERVIEW

Crosswind, a Shell and Eneco joint venture, was awarded the tender to develop the offshore Hollandse Kust Noord (HKN) wind farm, located 18.5km off the coast of Netherlands near the town of Egmond aan Zee. The consortium plans to have HKN operational in 2023 with an installed capacity of 759MW generating at least 3.3TWh per year. This is sufficient renewable power to supply more than 1 million Dutch households with green electricity.

Offshore wind farms produce intermittent electricity and balancing these dips and peaks and integrating this electricity into the national energy system requires new technologies. For this reason, the offshore wind farm will include several new technologies that could be implemented at full-scale in the future. The new technologies being explored include a floating solar park, a short-duration battery storage as well as long-term storage via green hydrogen produced by water electrolysis and subsequently consumed in a fuel cell. The combination of these individual measures, herein referred to as the Base Load Power Hub (BLPH) will ensure a continuous power supply regardless of the wind situation.

1.1.1 Project Location

The Hollandse Kust Noord (HKN) wind farm is located 18.5km off the coast of the Netherlands near the town of Egmond aan Zee.

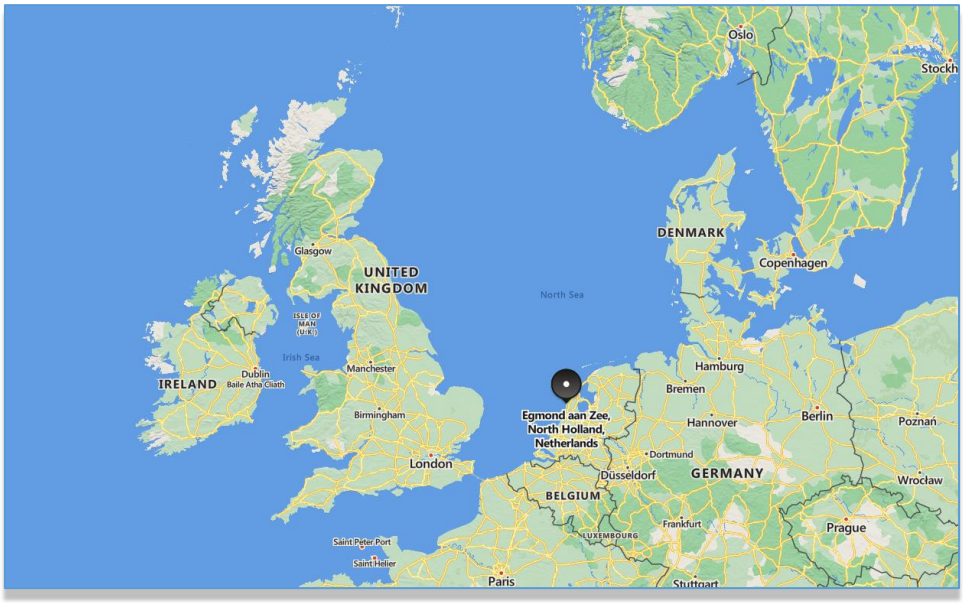


Figure 1.1 - HOLLANDSE KUST NOORD WIND PARK Location Map

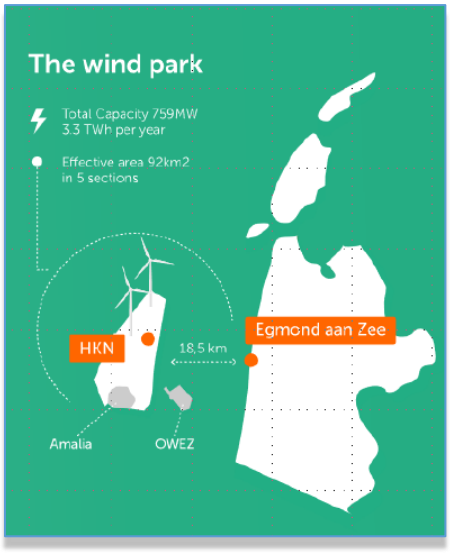


Figure 1.2 - Wind Park Details

The wind farm consist of No. 69 x 11.5MW wind turbine generators each to be installed on a dedicated monopile structure. A 70th monopile located on coordinates E 590719.1, N 5841602.3 is reserved for installing the platform accommodating the BLPH. The monopile structure was designed and installed by Van Oord Offshore Wind (VooW) and therefore not part of the BLPH scope.

1.1.2 Project Concept

All components included in the BLPH will be integrated onshore on a topsides and installed in an offshore location within the boundaries of the HKN wind farm. At its simplest, the BLPH will store energy during periods of high electricity generation from renewable sources (a wind turbine generator and the floating solar PV farm) and release it during periods of low generation. In practice. It is expected that the energy stored will supplement generation from renewable sources to ensure that at least 1.0MW of power is exported to the electrical grid regardless of wind/solar availability.

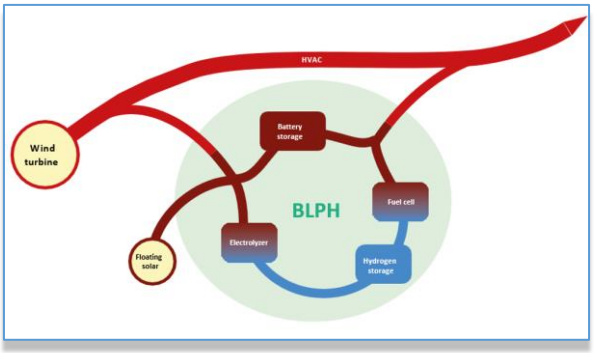


Figure 1.3 – BLPH Concept

Electricity in the BLPH will be stored in the form of electrons in a battery energy storage system (BESS) as well as converted into green hydrogen via water electrolysis. When the power output from the connecting wind turbine drops to below 1 MWe, the BLPH will return its stored energy to supplement the remaining power output. This will be by discharging the BESS, while stored hydrogen will be converted back into electricity using a fuel cell to extend the discharge duration.

The purpose of the BLPH s to function as a testbed for the integration of energy storage technologies with renewable generation. It is expected that equipment installed on the BLPH will operate as Normally Unmanned Installation for at least two (2) years with no or minimal maintenance and it will have its own independent control room with the ability to communicate with Crosswind's control room.

2 DOCUMENT SCOPE

The purpose of this document is to present the acceptance criteria for the execution of the offshore installations of Transition Piece, caisson frame and Topside within the BLPH project.

In detail:

1. Flange coupling and shimming requirement
2. Min requirement to disconnect the crane after installations
3. Min bolts number and pretension required prior to install the Caisson frame and Topside
4. Tightening force / bolts preload requested n each phase considering an overall safety factor

3 REFERENCES

3.1 CODES AND STANDARDS

Doc. No.	Description
/1/ BS EN ISO 19900	General requirements for offshore structures - 2019
/2/ BS EN ISO 19901-1	Specific requirements for offshore structures - Part 1: Metocean design and operating considerations - 2015
/3/ BS EN ISO 19901-3	Specific requirements for offshore structures – Part 3: Topsides structure - 2014
/4/ BS EN ISO 19901-5	Specific requirements for offshore structures – Part 5: Weight Management - 2021
/5/ BS EN ISO 19901-6	Specific requirements for offshore structures – Part 6: Marine Operations – 2009
/6/ BS EN ISO 19902	Petroleum and natural gas industries - Fixed steel offshore structures – 2020
/7/ ISO 19906:2019	Petroleum and natural gas industries – Arctic offshore structures
/8/ EN 1993-1-1	Design of steel structures - Part 1-1: General rules and rules for buildings
/9/ DNV-ST-N001	DNV GL - Marine operation and marine warranty - 2021
/10/ DNV-ST-0145	DNV, Offshore substations
/11/ DNV-RP-C201	DNV, Buckling Strength of Plated Structures, October 2010.
/12/ DNV-ST-0126	Support structures for wind turbine, 2018
/13/ DNV-RP-C205	Environmental conditions and Environmental loads, 2019
/14/ EN 1090-2	Execution of steel structures – Part 2 technical requirements for steel structures.

3.2 COMPANY SPECIFICATIONS

Doc. No.	Description
/15/ DEP 37.19.00.12	Gen - Offshore Topsides Structures
/16/ DEP 37.19.00.30	Gen - Fixed Steel Offshore Structures (Adoption of IOGP S-631-11, Amendments / Supplements to ISO 19902:2020).
/17/ DEP 37.81.10.19	Gen - Marine Operations Requirements – Loadout, Transportation and Installation of Offshore Structures (Amendments / Supplements to ISO 19901-6)

3.3 PROJECT DOCUMENTS

Doc. No.	Description
/18/ 123A90-DDL-ST-SP-90017	Structural Design Basis
/19/ 123A90-DDL-MD-RE-01006	Monthly Weight Report
/20/ 123A90-DDL-ST-RE-90013	BLPH Platform - TP-MP Flange Connection Verification

3.4 OTHER DOCUMENTS

Doc. No.	Description
/21/ D2281948 / 006	Tightening Specification - Offshore
/22/ D2703331 / 002	Shimming of Tower foundation and Tower flange
/23/ 123A90-DDL-ST-RE-90015	Caisson frame – in service, lifting and transportation design Report

4 DEFINITIONS AND ABBREVIATIONS

COMPANY or Client (CPY)	Crosswind
CONTRACTOR (CTR)	ROSETTI MARINO S.p.A.
PROJECT	HOLLANDSE KUST NOORD WIND PARK Project
T&I CONTRACTOR	DEME
BLPH	Base Load Power Hub
BL	Boat Landing
CF	Caisson Frame
CoG	Centre of Gravity
CW	CrossWind
CTV	Crew transfer vessel
DAF	Dynamic Amplification Factor
El.	Elevation
HAT	Highest Astronomical Tide
HKN	Hollandse Kust Noord
LAT	Lowest Astronomical Tide
LRFD	Load and Resistance Factor Design
MSL	Mean Sea Level
NTE	Not-to-Exceed
OD	Outside Diameter
PG	Plate Girder
SHL	Static Hook Load
T&I	Transport & Installation
ToS	Top of Steel
UC	Unity Check
UDL	Uniformly Distributed Load
WTG	Wind Turbine Generator
W2W	Walk to Work

Table 4.1 - Definitions and Abbreviations

5 BLPH PLATFORM DESCRIPTION

The final configuration of BLPH platform is shown in fig. 5.1.

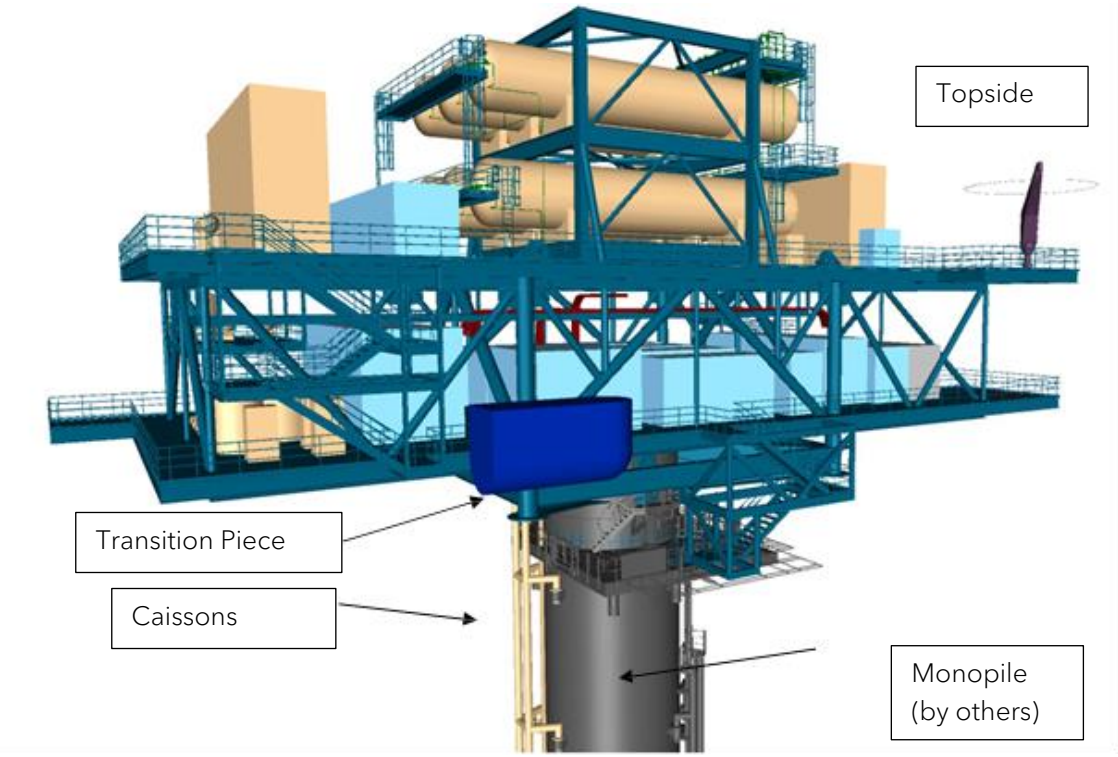


Figure 5.1 – BLPH platform

The monopile CW70 was installed in Jan. 2023.

5.1 WEIGHTS OF THE STRUCTURES

The lifting weights of the structures that are going to be installed are derived from WCR, ref. /19/ and summarized in Table 5.1.

BLPH - TOPSIDE (NO LIVE LOAD AND SNOW) - Summary by Phase

Phase Code	Phase Description	Base Wt. (t)	Center of Gravity			Design Gross (Expected) Wt. (t)	Center of Gravity		
			Northing (m)	Easting (m)	Elevation (m)		Northing (m)	Easting (m)	Elevation (m)
LO	Loadout	1612	19,7	7,9	29,3	1802	19,7	7,9	29,3
ST	Sea Transport	1612	19,7	7,9	29,3	1802	19,7	7,9	29,3
OP	Operating weight (Dry + Contents)	1655	19,6	8,0	29,3	1851	19,6	8,0	29,3
L	Lifting	1612	19,7	7,9	29,3	1802	19,7	7,9	29,3

BLPH - TRANSITION PIECE (TP) - Summary by Phase

Phase Code	Phase Description	Base Wt. (t)	Center of Gravity			Design Gross (Expected) Wt. (t)	Center of Gravity		
			Northing (m)	Easting (m)	Elevation (m)		Northing (m)	Easting (m)	Elevation (m)
LO	Loadout	263	19,8	8,5	20,1	290	19,8	8,5	20,1
ST	Sea Transport	263	19,8	8,5	20,1	290	19,8	8,5	20,1
OP	Operating weight (Dry + Contents)	253	19,9	8,5	20,3	280	19,9	8,5	20,3
L	Lifting	230	19,7	8,6	20,3	254	19,7	8,6	20,3

Table 5.1 – lifting weights (t)

5.1.1 BLPH Global Reference System

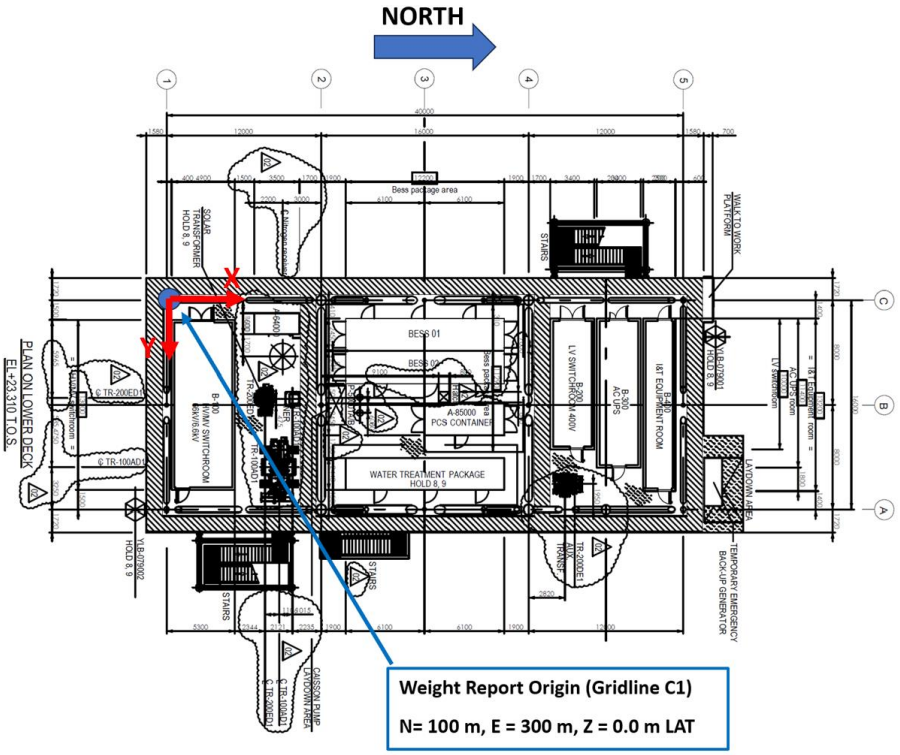


Figure 5.2 – BLPH platform reference system – plan view

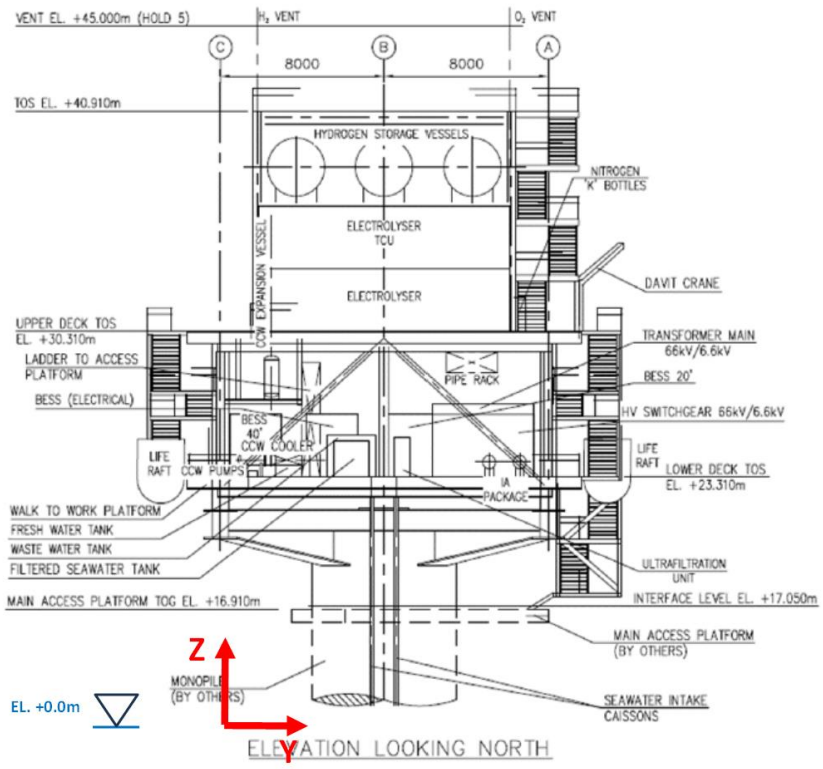


Figure 5.3 – BLPH platform reference system - Elevation

6 ENVIRONMENTAL LOADS

The following environmental loads shall be considered during installation phase and during stand-by phase

- Wind;
- Wave and current

6.1 WIND LOADS

Operating wind loads will be defined considering 1-year return period. The 100-years return period will be used for the extreme environmental conditions. The equivalent static wind force, F_{wind}, acting on the structures may be calculated according to Refs. /2/and /6/:

$$F_{wind} = \frac{1}{2}\ \rho_a\ U_w\ C_S\ A_r$$

Where:

ρ = air density (1.225kg/m^3)

A = area of the object (m^2)

U = wind speed (m/s)

Cs = shape coefficient

As per Ref./2/ the wind speed in a 3s gusts is appropriate for maximum quasi-static local or global actions on structures whose maximum horizontal dimension is less than 50 m.

Shape coefficient Cs=1 will be considered for overall projected area of structures in global analyses.

Wind loads will be concurrent with wave and current loads.

Omni-Directional wind speed data are reported in Table 6.1 , from Ref./18/.

Averaging Time	Return period (years)						
	1	2	5	10	50	100	1000
1hr	31.8	33.4	35.1	36.4	39.1	40.1	43.4
10 min	33.7	35.5	37.4	38.8	41.7	42.9	46.5
3s	39.4	41.6	44.1	45.9	49.7	51.1	56.0

Table 6.1 - Omni-Directional Wind velocities [m/s] at 125 m MSL

Wind speeds are provided at 125m MSL. Wind speeds at any specified averaging time or elevation, will be calculated accordingly.

Wind speed @ 10 m elevation, 3s time, back figured from wind speed at El. +125.000 m result:

- 24.83 m/s Operating, 30.86 m/s Extreme

Wind forces acting on Topside and respective resultants along global X and Y directions have been calculated as per following tables.

Operating Wind Global forces X direction (Positive / Negative)									
Load Condition	**Location**	**Descr.**	**L [m]**	**H [m]**	**N**	**A [m2]**	**max el.**	**p [kN/m2]**	**F [kN]**
WOPX / WONX	BELOW LOWER DECK	walkways N	1.5	1	1	1.5	23.31	0.78	1.2
		center	40	1	1	40	23.31	0.78	31.2
		laydown	4.5	1	1	5	23.31	0.78	3.5
	BETWEEN DECKS	walkways N	1.5	1.5	1	2.25	26.81	0.79	1.8
		center	32.8	7	1	229.6	26.81	0.79	182.0
		laydown	4.5	1.5	1	6.75	26.81	0.79	5.4
	ABOVE UPPER DECK	walkways	1.5	1.5	2	4.5	31.81	0.81	3.6
		center	14	1.5	1	21	31.81	0.81	17.0
		fuel cell	3	6.4	1	19.2	36.71	0.82	15.8
		Pau	16	8	1	128	38.31	0.83	106.0
		Elogen	7	9	1	63	39.31	0.83	52.2
	STAIRS	stairs	7.2	3.5	1	25.2	25.06	0.78	19.6
			7.2	3.5	1	25.2	28.56	0.79	20.0
	PAU	(from AUTOCAD propmass area)				102.06758	21.5	0.77	78.6
							TOT		**537.8**
							LCOMB WOPA/ WOPE		**538.5**

Operating Wind Global Forces Y direction (Positive / Negative)									
Load Condition	**Location**	**Descr.**	**L [m]**	**H [m]**	**N**	**A [m2]**	**max el.**	**p [kN/m2]**	**F [kN]**
WOPY / WONY	BELOW LOWER DECK	walkways	1.64	1	2	3.28	23.31	0.78	2.56
		center	16	1	1	16	23.31	0.78	12.47
	BETWEEN DECKS	walkways	1.64	1.5	2	4.92	26.81	0.79	3.90
		center	16	7	1	112	26.81	0.79	88.80
	ABOVE UPPER DECK	walkways	1.64	1.5	2	4.92	31.81	0.81	3.98
		center	16	6.4	1	102.4	36.71	0.82	84.21
		laydown	2.86	1.5	1	4.29	31.81	0.81	3.47
	STAIRS	stairs	3.6	3.5	2	25.2	25.06	0.78	19.64
		stairs	3.6	3.5	2	25.2	28.56	0.79	19.98
		stairs	3.6	1.5	2	10.8	31.81	0.81	8.74
	PAU	(from AUTOCAD propmass area)				102.06758	21.5	0.77	78.59
							TOT		**326.35**
							LCOMB WOPC / WOPG		**327.35**

Table 6.2 - Operating Wind Forces along X and Y direction

Extreme wind forces and respective resultants along global X and Y directions have been calculated as per following tables.

Extreme Wind Global Forces X direction (Positive / Negative)									
Load Condition	**Location**	**Descr.**	**L [m]**	**H [m]**	**N**	**A [m2]**	**max el.**	**p [kN/m2]**	**F [kN]**
WEPX / WENX	BELOW LOWER DECK	walkways N	1.5	1	1	1.5	23.31	1.30	2.0
		center	40	1	1	40	23.31	1.30	52.1
		laydown	4.5	1	1	5	23.31	1.30	5.9
	BETWEEN DECKS	walkways N	1.5	1.5	1	2.25	26.81	1.32	3.0
		center	32.8	7	1	229.6	26.81	1.32	304.0
		laydown	4.5	1.5	1	6.75	26.81	1.32	8.9
	ABOVE UPPER DECK	walkways	1.5	1.5	2	4.5	31.81	1.35	6.1
		center	14	1.5	1	21	31.81	1.35	28.4
		fuel cell	3	6.4	1	19.2	36.71	1.37	26.4
		Pau	16	8	1	128	38.31	1.38	177.0
		Elogen	7	9	1	63	39.31	1.38	87.1
	STAIRS	stairs	7.2	3.5	1	25.2	25.06	1.30	32.8
			7.2	3.5	1	25.2	28.56	1.32	33.4
	PAU	(from AUTOCAD propmass area)				102.0676	21.5	1.29	131.2
							TOT		**898.2**
							LCOMB WEXA / WEXE		**901.5**

Extreme Wind Global Forces Y direction (Positive / Negative)									
Load Condition	**Location**	**Descr.**	**L [m]**	**H [m]**	**N**	**A [m2]**	**max el.**	**p [kN/m2]**	**F [kN]**
WEPY / WENY	BELOW LOWER DECK	walkways	1.64	1	2	3.28	23.31	1.30	4.27
		center	16	1	1	16	23.31	1.30	20.82
	BETWEEN DECKS	walkways	1.64	1.5	2	4.92	26.81	1.32	6.51
		center	16	7	1	112	26.81	1.32	148.30
	ABOVE UPPER DECK	walkways	1.64	1.5	2	4.92	31.81	1.35	6.65
		center	16	6.4	1	102.4	36.71	1.37	140.64
		laydown	2.86	1.5	1	4.29	31.81	1.35	5.80
	STAIRS	stairs	3.6	3.5	2	25.2	25.06	1.30	32.80
		stairs	3.6	3.5	2	25.2	28.56	1.32	33.37
		stairs	3.6	1.5	2	10.8	31.81	1.35	14.60
	PAU	(from AUTOCAD propmass area)				102.0676	21.5	1.29	131.25
							TOT		**545.0**
							LCOMB WEXC / WEXG		**546.7**

Table 6.3 - Extreme Wind Forces along X and Y direction

6.2 WAVE AND CURRENT LOADS

The inertial loading due to wave and current actions on the monopile will be considered for TP and Topside structural design and check. Maximum accelerations at El.+28 m LAT reported in Table 6.4 will be applied to permanent loads to evaluate wave inertial forces.

Case	Location	Elevation (LAT) [m]	Sea State	Max acceleration [m/s2]
Operational	Topsides CoG	28	Normal	0.67
Extreme	Topsides CoG	28	Extreme	1.61

Table 6.4 - Topsides Accelerations from Wave Loading on Monopile

7 FLANGE COUPLING - SHIMMING REQUIREMENTS

After the TP set down on monopile (MP) a minimum number of bolts will be installed to make the TP stable on MP allowing for crane disconnection.

Prior to perform the bolting connection the following checks will be performed.

7.1 MOUNT EARTHING CABLE/S

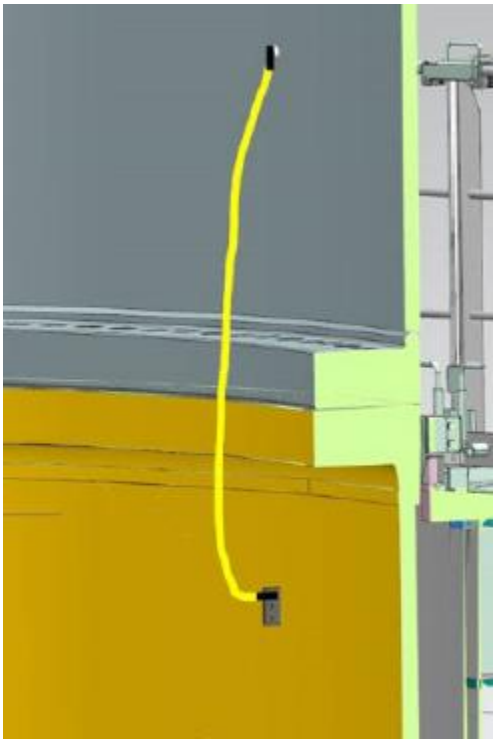


Figure 7.1 – example of mounting earthing cable

7.2 FLANGE ALIGNMENT

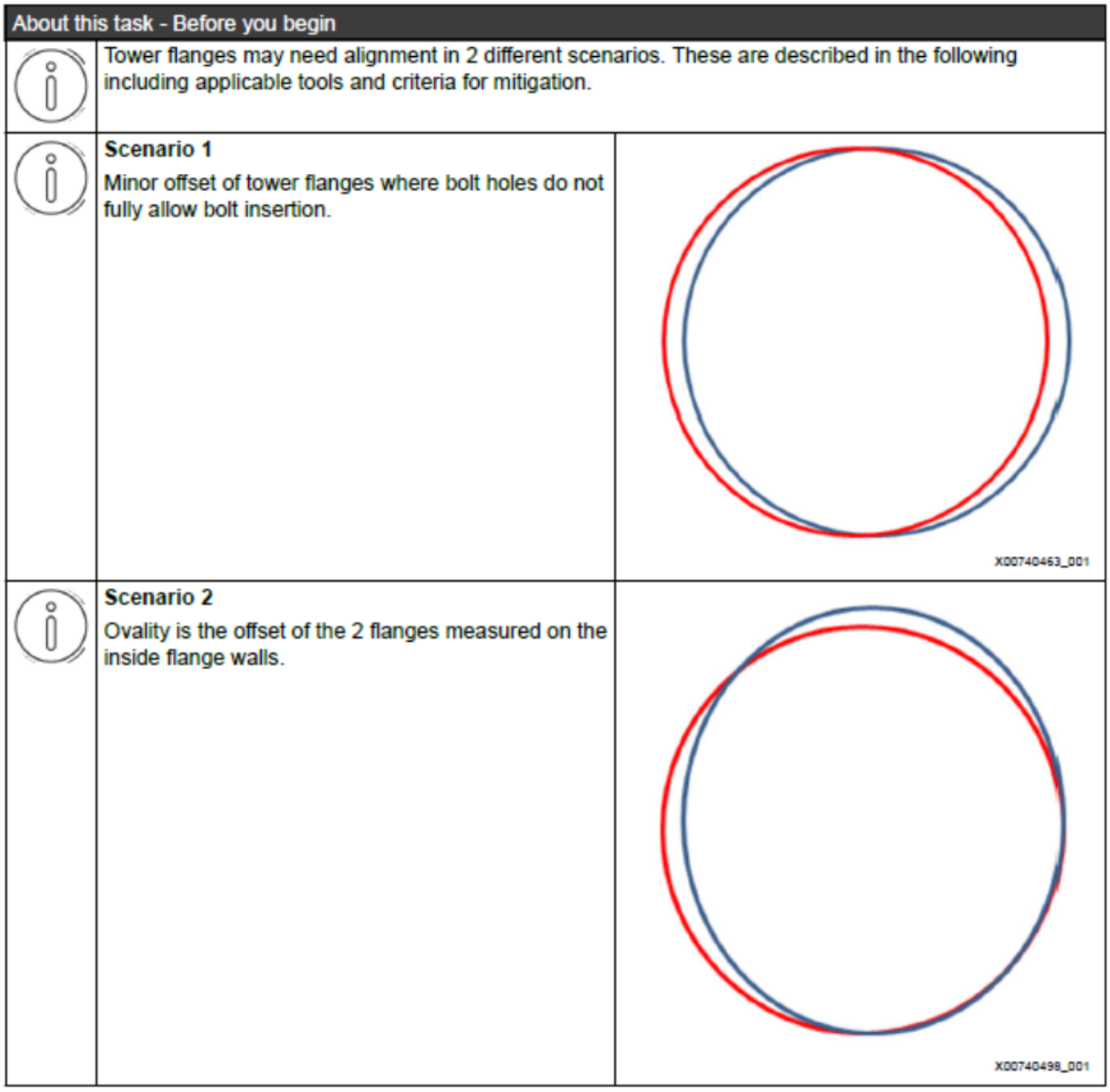


Figure 7.2 – Flange alignment

7.2.1 Scenario 1

In case of scenario 1 alignment will be performed using tag lines from HLV and suitable pins preinstalled on TP flange.

7.2.2 Scenario 2

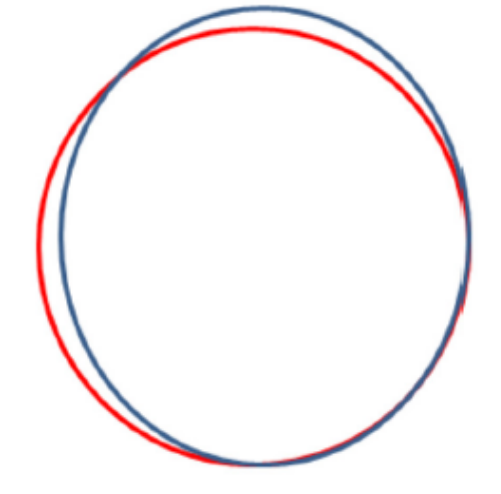
Scenario 2

Alignment of tower flanges in case of ovality of flanges up to 10 mm.

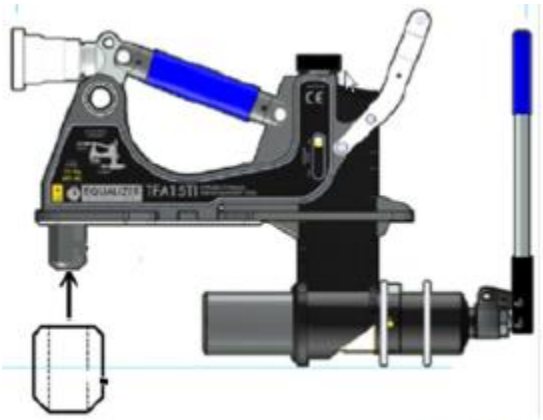
Ovality is measured at the offset of the two flanges where the difference is the biggest. Measurements are done on the inside flange walls.

Ovality of more than 10 mm is not approved.

In case of ovality of more than 10 mm, an NCR must be created.



Use flange alignment tool (e.g. Enerpac TFA series tool). In general it is allowed to apply up to maximum pump pressure. If maximum pump pressure is not sufficient to align the flanges, then NCR must be created.



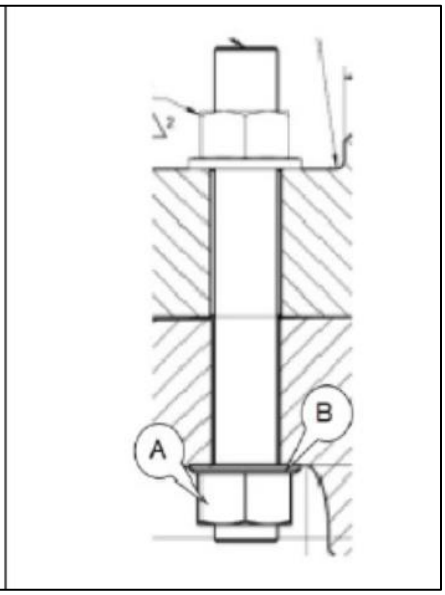
NOTE: never try to hit studs into place using a hammer

7.3 REQUIREMENT OF SHIMMING PLATES

7.3.1 Step 1

Ensure threads in M64 studs and nuts are undamaged.

Place the washers (B) with the chamfered side towards the nut (A).



7.3.2 Step 2

Install the bolts, with washers. Definition of number of bolts required for each phase is presented in sections 8 and 9.

7.3.3 Step 3

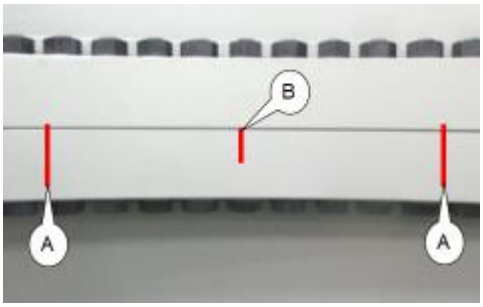
Use a nut runner to tighten all the evenly spaced studs to approximately 1500 Nm (about 10% final tension).

7.3.4 Step 4

Inspect for airgaps between the 2 flanges after applying 10% tightening. The shimming is requested where the local air gap is > 1 mm, measuring it from the inside and at bolt axis radius (MP flange has minor tilt for hammering purpose).

4a) Insert feeler gauge between every three bolt holes all the way around the flange. If an air gap is identified insert gauge between every bolt hole until the air gap ends.

4b) Mark-up the start and the end (A) of all air gaps of more than 1mm. Mark the air gap high spot which is the location where the air gap is widest (B). Note the size of the air gap at this location.



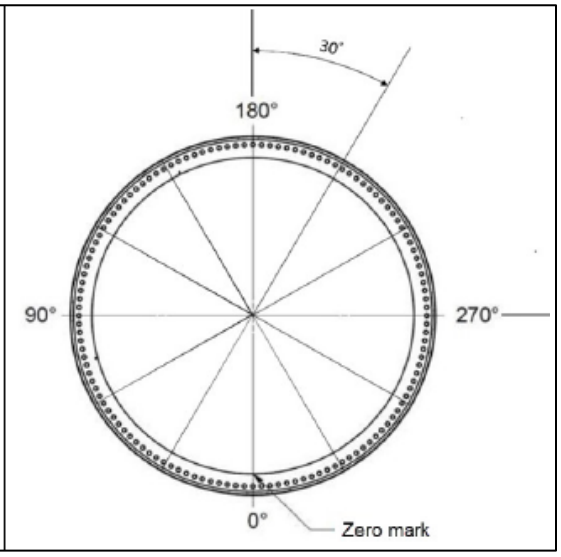
4c)

To evaluate if the air gap can be approved or not, the air gap high spot and the start/stop markings must be used.

Identify if the start stop markings are inside or outside a 30° angle by converting angle into amount of bolt holes.Divide the total amount of bolt holes in the flange by 12 (equals 30°).Example: 143 bolts/12 ≈ 12 bolts (equals 30° angle).

Air gap <30° is a local air gap.

Air gap >30° is a global air gap.



Air Gap at high spot	Local airgap (< 30deg angle between start and stop)	
< 1mm	Approved	Continue to final tightening
1-3mm	Shim	Shim

Air Gap at high spot	Global airgap (> 30deg angle between start and stop)	
< 1 mm	Approved	Continue to final tightening
2-4mm	Shim	Shim

7.3.5 Shim plate

The existing flange on MP has the following flatness (well below the limit of +/- 1mm):

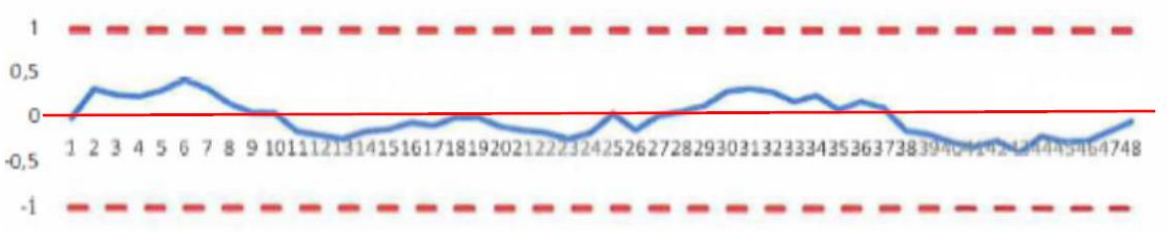


Figure 7.3 – MP flange flatness – yard survey

Dimensional control of the new flange on TP will allow preliminary verification of the required shimming. Accordingly, will be provided and made available on-board shim plates of different thicknesses 0.5mm, 1mm and 2mm. Example of shim plate design:

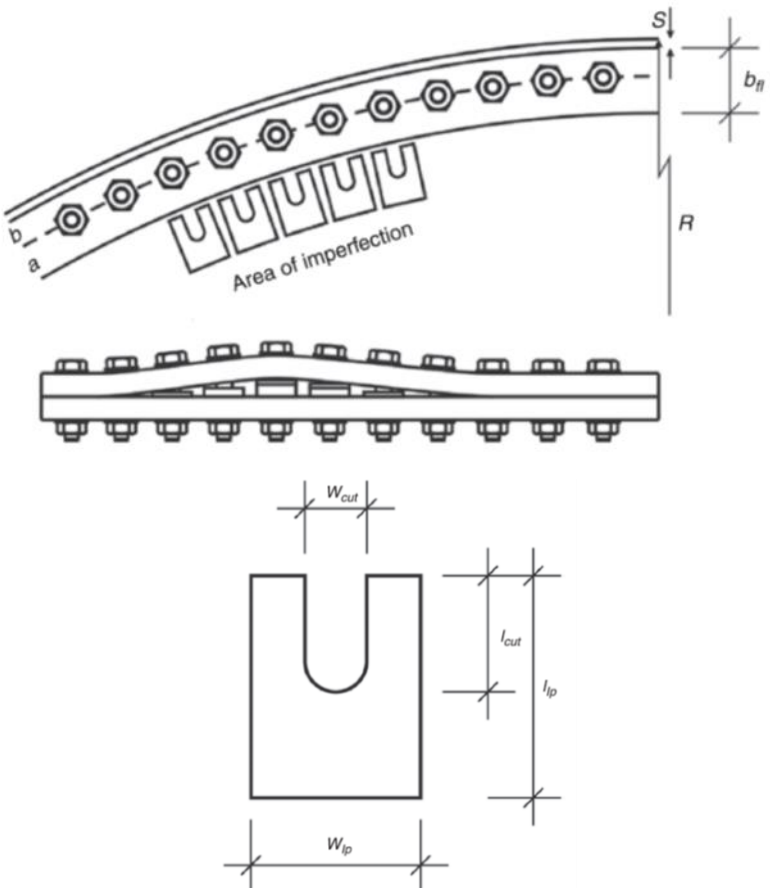


Figure 7.4 – example of shim plates – made in Stainless steel

8 INSTALLATION PHASE 1 – TP INSTALLATION

The purpose of the following sections is to verify the stability of the installed structures with respect to the minimum number of bolts and their pretensioning necessary to allow for the possible abandonment of the structure in case of adverse weather conditions.

The base case considers the installation and tensioning of the bolts as continuous operation following the pretensioning procedure.

This first section verifies the actions on TP that allow to disconnect the crane after set-down and start working on TP. The TP will be installed on MP by using suitable installation bumpers that will guide the TP in the correct position and orientation. After the set down it is necessary to start the bolting operations.

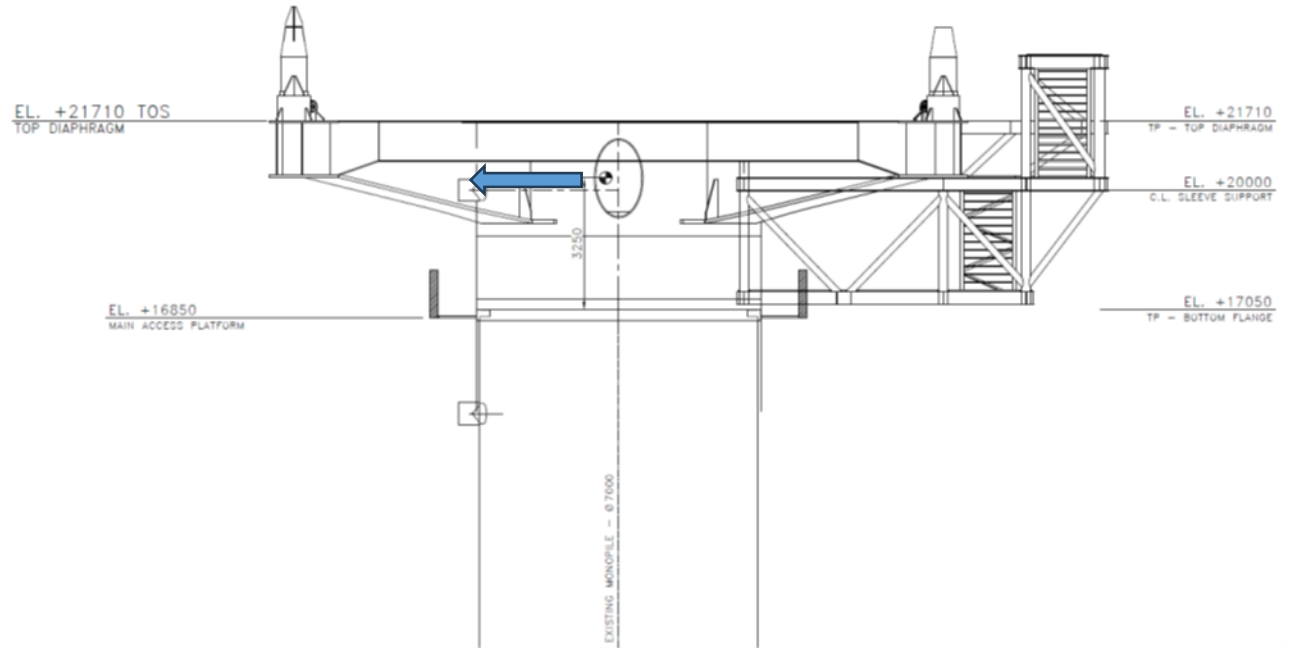


Figure 8.1 – TP set on MP

8.1 STABILITY CHECK

Vertical force = TP self-weight in lifting configuration= 254 ton = 2492 kN

Horizontal forces:

- Wind (ref section 6.1)

EXTREME WIND							
U_{w0} [m/sec]	z [m]	C	$U_{w,1h}$ (z) [m/sec]	t [sec]	I_u (z)	$U_{w,T}$ (z) [m/sec]	wind pressure p [kN/m^2]
30.86	125.000	0.136	41.45	3	0.080	51.10	1.60
30.86	10.000	0.136	30.86	3	0.140	43.38	1.15
30.86	20.000	0.136	33.76	3	0.120	45.53	1.27

Fwind = (5 x 16m) x 1.27 = 101.60 kN

- Wave (ref section 6.2) – applied as inertia load

  Fwave = 2492*(1.61g/9.81) = 2492 kN*0.16 = 410 kN

Total horizontal force (both considered concurrent and Extreme) = 410+101.6 = 511.6 kN

Extreme Horizontal force is totally resisted by friction: 511.6 < 2492*0.25 = 762 kN (SF = 1.2)

Overturing check:

Overturning moment = 511.6 * 3.25m *1.30 = 2161.5 kNm (including factor = 1.30)

e = M / N = 2161.5/2492 = 0.87 m < R/8 = 0.875m section fully compressed

NOTE:

Technicians are allowed to work on TP being verified the stability check against extreme conditions.

9 INSTALLATION PHASE 2 - CF INSTALLATION

This section defines the min. number of bolts, and the tightening force required to proceed with the installation of Caisson Frame.

Caisson Frame is fully supported by hanger flanges at EL. +20.00m

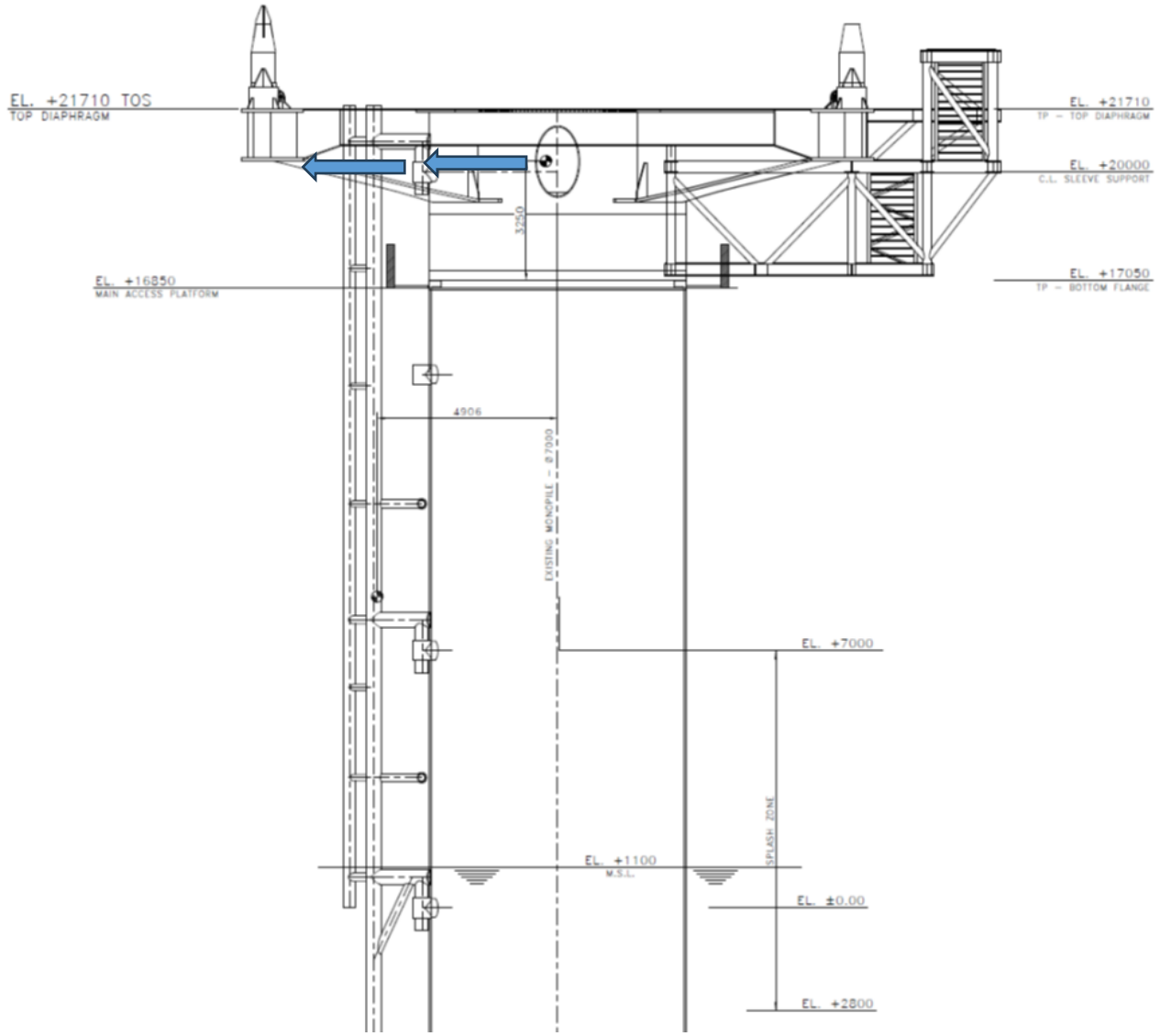


Figure 9.1 – CF installed

9.1 STABILITY CHECK

Extreme metocean conditions are considered.

Vertical forces:

- TP self-weight = 254 ton = 2492 kN
- CF self-weight= 35 ton = 350 kN

Horizontal forces:

- Wave (ref section 6.2) – inertia load

  Fwave = (2492+350)*(1.61g/9.81) = 2842*0.16 = 455 kN TP+CF

  Fwave on CF = 322+124=446 kN extreme wave transversal reaction on CF supports @ +20.0m LAT (ref /23/)

Overturing check:

Overturning moment = [(455*3.25m)+(446*2.95m)]*1.30 = 3661 kNm (including factor = 1.30)

e = M / N = 3661/(2492+350) = 1.30m > R/8 = 0.875m

Bolts are required to connect TP with monopile.

9.1.1 Min. bolt required

The min. number of bolts required is governed by the increase of vertical force necessary to satisfy the overturning check.

0.875 = M/N → N = M / e = 3661/0.875 = 4184 kN with Δ=4184-(2492+350) = 1342 kN

Min. bolt torque = 1500Nm (about 10% of final torque)

M = k*d*Tension

Tension = M / (k*d) = 1500 / (0.10*64/1000) = 234 kN/bolt

(with k = 0.10 assumed equal to the k used in Siemens installations)

1342/234 = 5.7 bolts assumed 8 bolts

NOTE:

CF is allowed to be installed once the 10% of the bolts, equal to 16 bolts, equally distributed on flange, will be installed and tightened 10% of final tightening force (= about 1500 Nm).

The checks were performed considering the extreme environmental conditions.

10 INSTALLATION PHASE 3 – TOPSIDE INSTALLATION

This section defines the min. number of bolts, and the tightening force required to proceed with the installation of Topside.

The worst installation condition predicted considers the Topside suspended on Crane hook (min. vertical force) associated to the max impact force applied horizontally at the top of TP primary stabbing guide.

Once installed the topside self-weight stabilizes the flange connection against overturning moment.

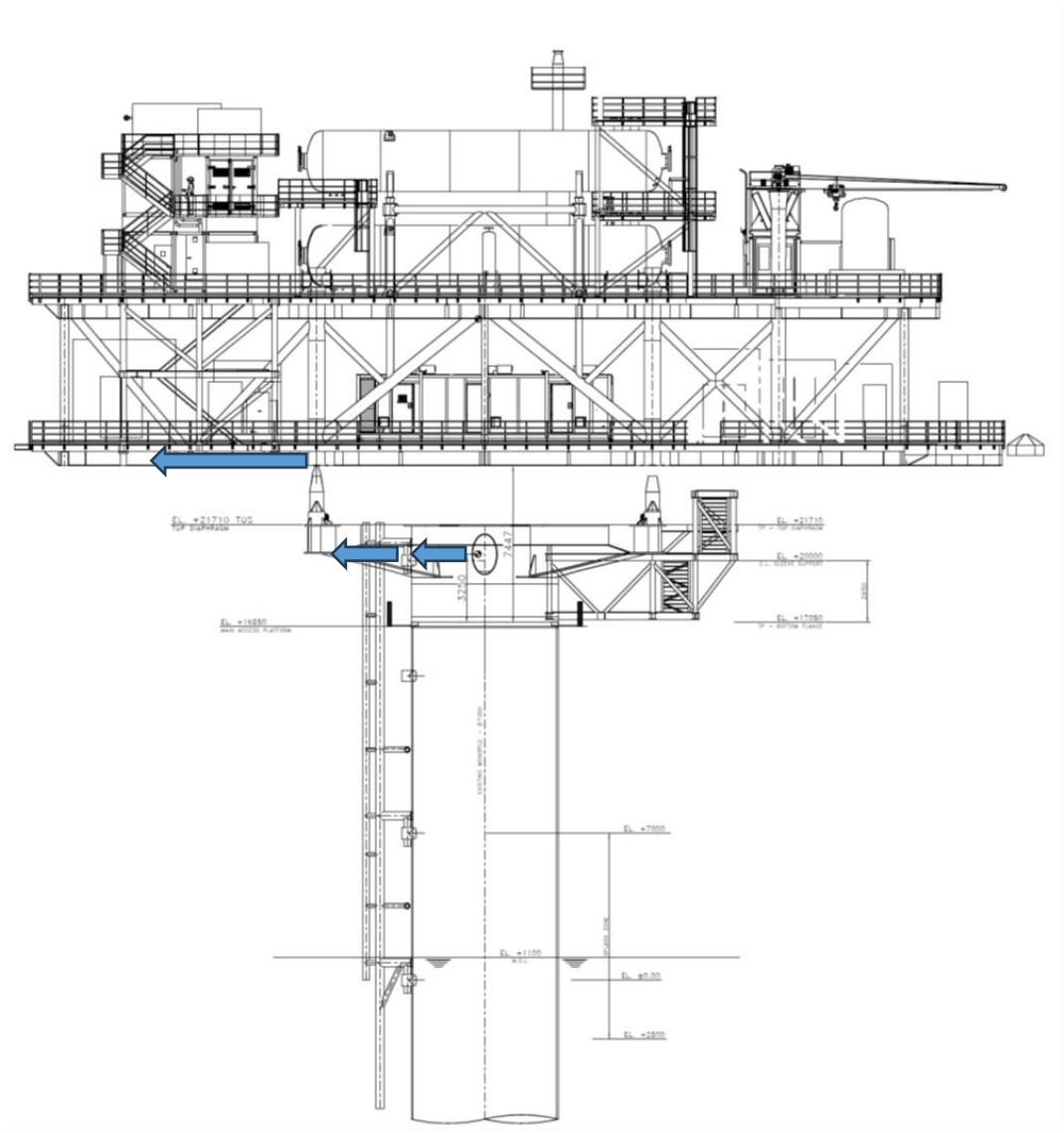


Figure 10.1 – Topside installation phase

10.1 STABILITY CHECK – INSTALLATION

In this phase operating metocean condition are considered.

Vertical forces:

- TP self-weight = 254 ton = 2492 kN
- CF self-weight= 35 ton = 350 kN

Horizontal forces:

- Wave (ref section 6.2)

  Fwave = (2492+350)*(0.67g/9.81) = 2842 kN*0.068 = 194.1 kN TP+CF

  Fwave on CF = 322+124=446 kN / 1.30 = 343 kN operative wave transversal reaction on CF supports @ +20.0m LAT (ref /23/). Extreme wave force decreased by ULS factor 1.3.

- Impact load

  Topside impact load = 0.10*1802 = 180 ton = 1800 kN

Overturing check:

Overturning moment = [(194.1*3.25m)+(343*2.95)+(1800*7.447)]*1.30 = 19561 kNm (including factor = 1.30)

Bolts with pretension are required to secure the TP.

10.1.1 Min. bolt required

The min. number of bolts required is governed by the increase of vertical force necessary to satisfy the overturning check.

0.875 = M/N → N = M / e = 19561/0.875 = 22356 kN with Δ=22356-2842 = 19514 kN

Min. bolt torque = 1500Nm (about 10% of final torque)

M = k*d*Tension

Tension = M / (k*d) = 1500 / (0.10*64/1000) = 234 kN/bolt

(with k = 0.10 assumed equal to the k used in Siemens installations)

19514/234 = 83.4 bolts

NOTE:

Topside is allowed to be installed once the 50% of the bolts, equal to 80 bolts, equally distributed on flange, will be installed and tightened 10% of final tightening force (= about 1500 Nm).

10.2 STABILITY CHECK – TOPSIDE PLACED ON TP

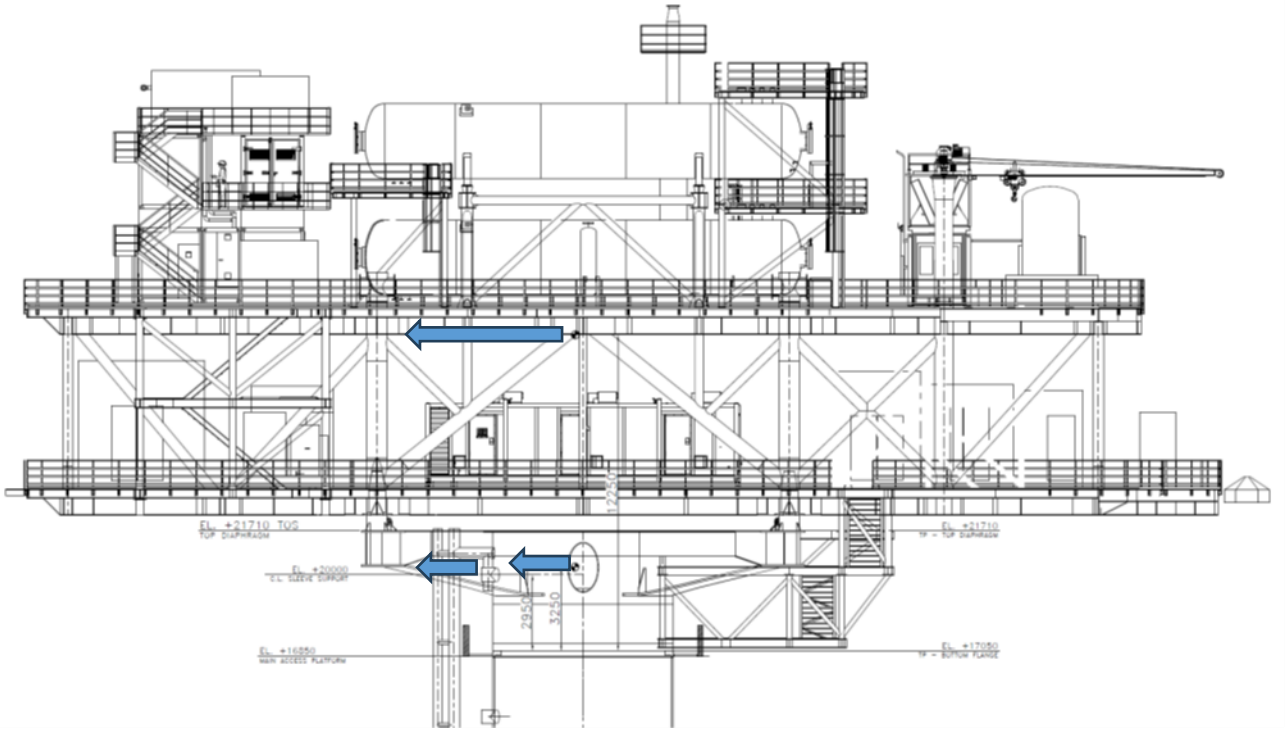


Figure 10.2 – Topside placed on TP

In this phase extreme metocean conditions are considered.

Vertical forces:

- TP self-weight = 254 ton = 2492 kN
- CF self-weight= 35 ton = 350 kN
- Topside self-weight = 1802 ton = 17678 kN

Horizontal forces:

- Wind (ref section 6.1)

  Fwind = 901.5 kN

- Wave (ref section 6.2) – inertia load

  Fwave = (2492+350+17678)*(1.61g/9.81) = 20520 kN*0.16 = 3368 kN TP+CF+TOPS

  Fwave on CF = 322+124=446 kN extreme wave transversal reaction on CF supports @ +20.0m LAT (ref /23/)

Total horizontal force (both considered concurrent and Extreme) = 901.5+3368+446=4715.5 kN

Overturing check:

Overturning moment = [(901.5*12.25m)+(3368*12.25)+(446*2.95)]*1.30 = 69702 kNm (including factor = 1.30)

10.2.1 Min. bolt required

e = M/N = 69702 / (2492+350+17678) = 69702 / 20520 = 3.40 m > R/8 = 0.875m

Bolts are required to connect TP with monopile. The min. number of bolts required is governed by the increase of vertical force necessary to satisfy the overturning check.

0.875 = M/N → N = M / e = 69702/0.875 = 79660 kN with Δ=79660-20520 = 59140 kN

Min. bolt torque = 8100Nm (75% of final torque – 1st stage tensioning)

M = k*d*Tension

Tension = M / (k*d) = 8100 / (0.10*64/1000)/1000 = 1265 kN/bolt

(with k = 0.10 assumed equal to the k used in Siemens installations)

69702/1265 = 55 bolts

NOTE:

Topside is allowed to be left in place once the 50% of the bolts, equal to 80 bolts, equally distributed on flange, will be installed and tightened 75% of final tightening force (torque = 8100 Nm).

11 FINAL TIGHTENING

The final phase considers the installation of the remaining 50% of bolts tensioned to 75% of final torque. Then all the bolts will be tensioned 100% (it is not allowed to proceed with final tensioning prior to complete all bolts tension to 75%).

Bolts tightening will be performed in accordance with /12/. Bolts ISO 898 cl.10.9.

Type of Fastener ISO	STUD BOLT M64
Property class	10.9
Torque (Nm)	11000
Two-stage tightening 1st stage (Nm) 75% 2nd stage (Nm)	 8100 11000

Table 11.1 – MP – TP flange connection – Bolts torquing

Note: 1686 kN is the final tensioning calculated in design report, the corresponding torque is calculated with the formulas to link Torque and Tension ($F_{p,c}$) :

$M = k*d*F_{p,c}$ (ref. /14/) with k = 0.10 (ref. siemens procedure /21/)