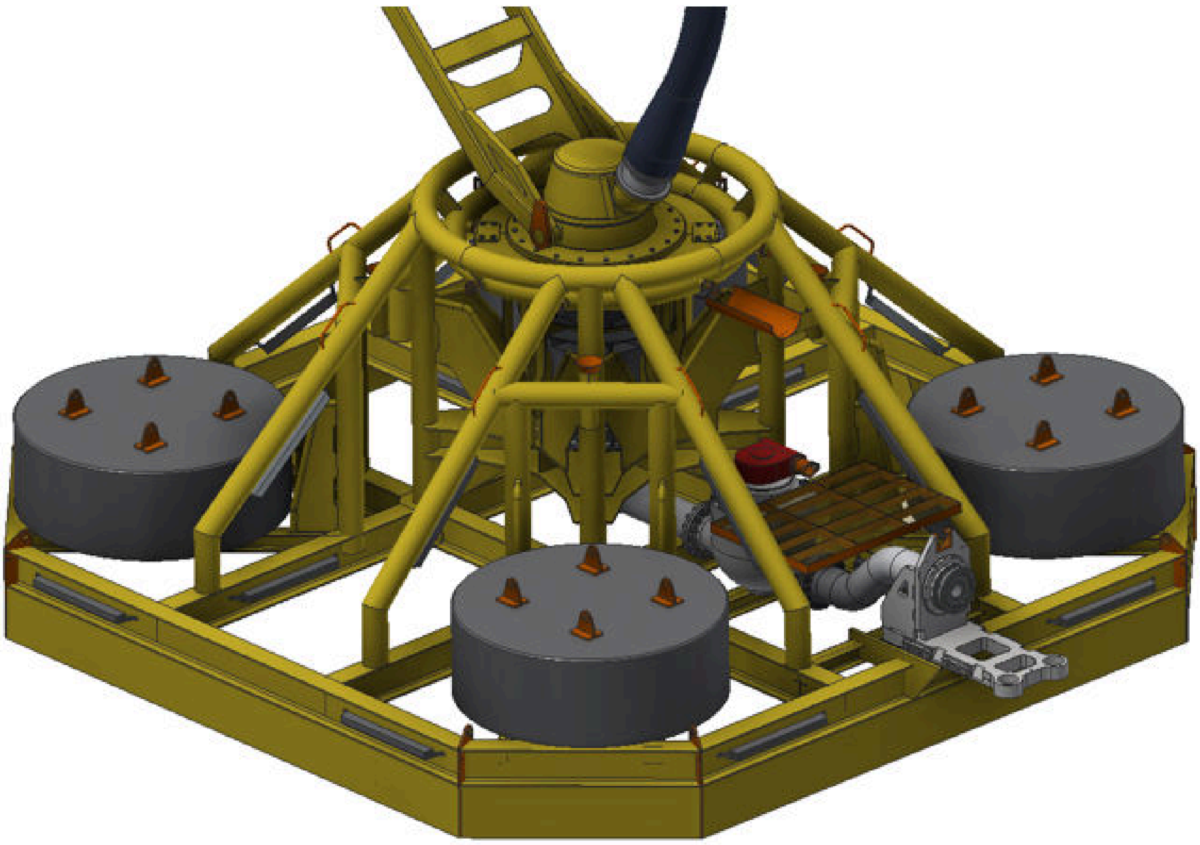
Submerged Loading System - SLS
System Overview



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1 Overview and system design

All critical parts (horizontal tie-in system, vertical tie-in system and swivel) are field proven technology.

The main elements that constitute the submerged loading system are:

- Gravity Base Structure
- Offloading Riser Assembly
- Lower riser end vertical tie-in assembly with swivel
- Messenger Line Arrangement for pick-up of riser
- Transducers and transponder array for localizing the messenger line and monitoring orientation of riser on seabed

The system can also be delivered with:

- Export line from platform or subsea tank to SLS
- Riser or J-tube with hang-off clamp to platform deck (as part of the export line)

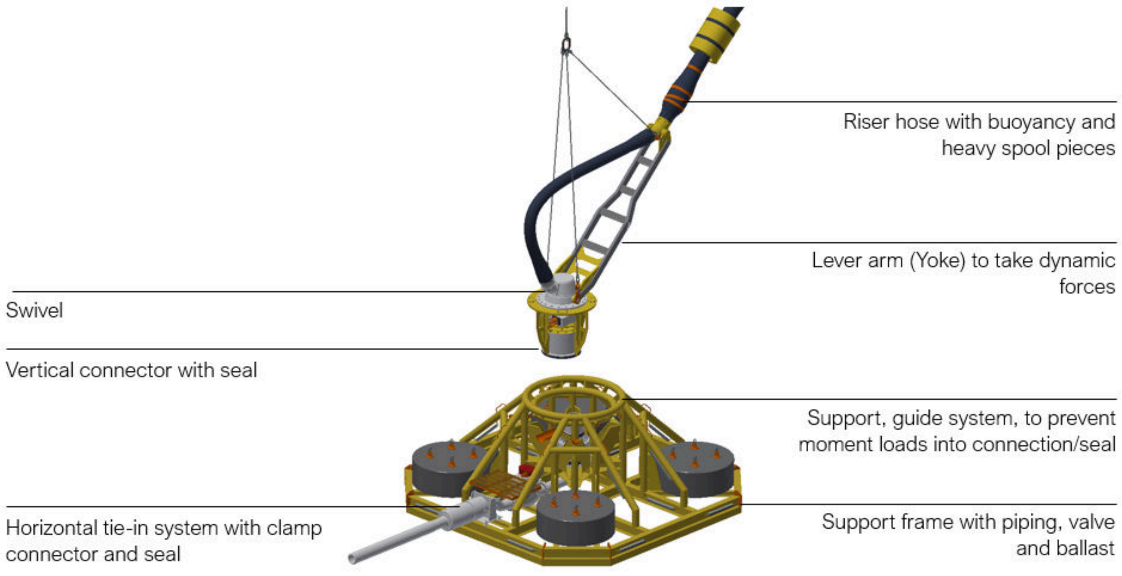


Figure 1-1 Gravity base structure

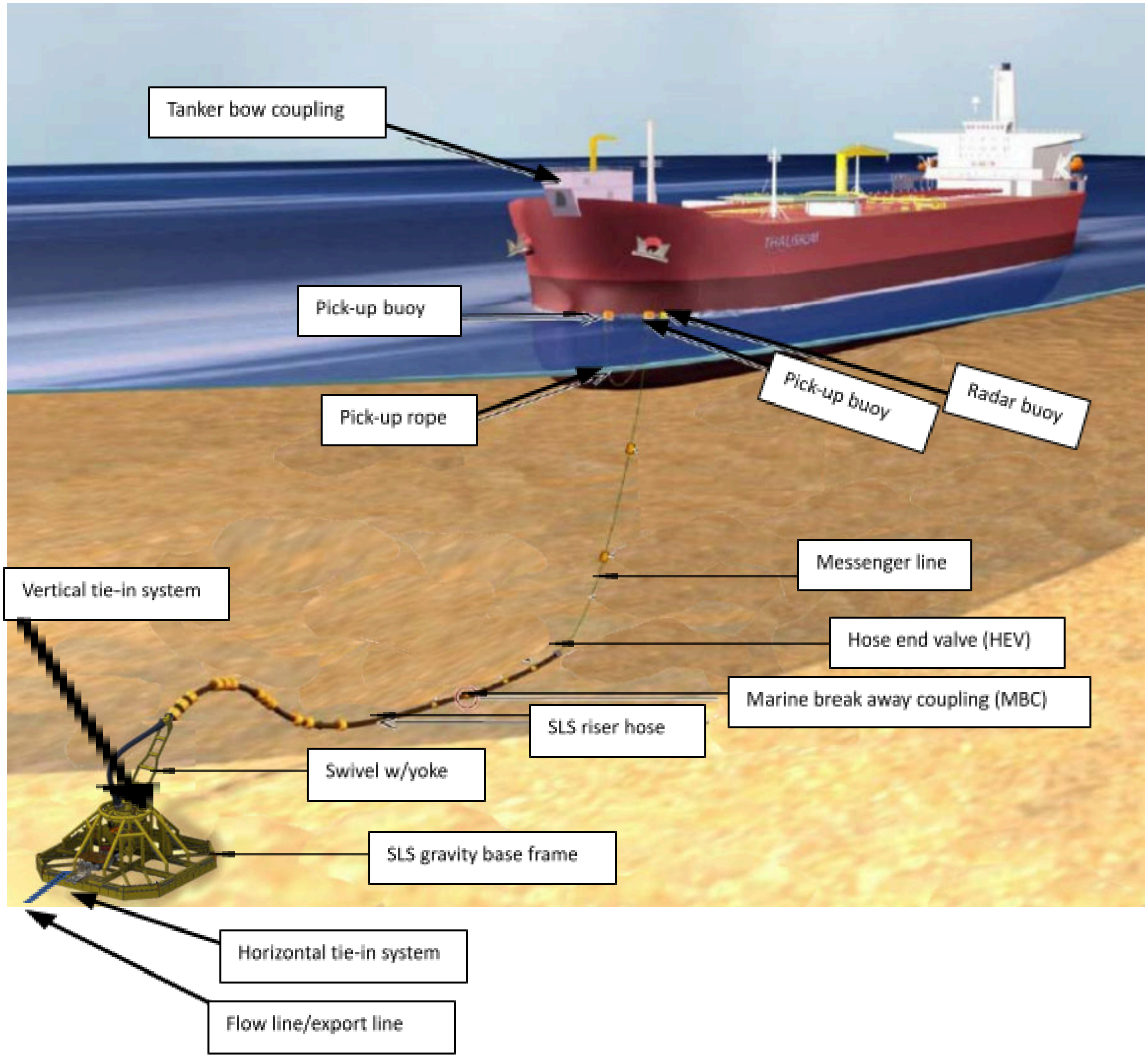


Figure 1-2 System overview

2 Horizontal tie-in system

The horizontal tie-in system comprises of:

- Landing and alignment system
- Connector and hubs
- Seal
- ROV operated stroking tool and torque tool
- ROV operated tools for seal face cleaning and seal replacement. A hub face clean tool can also be provided

The tie-in system is field proven for both flexible and rigid pipe (spool).

The tie-in system comes in a variety of dimensions and can be designed to take any typical pipe dimension for these types of applications. The tie-in system is a robust and sturdy design. The capacity of the system is more than sufficient for these applications.

The connector has a double acting metal seal which prevents leakage and external termination of the oil/gas.

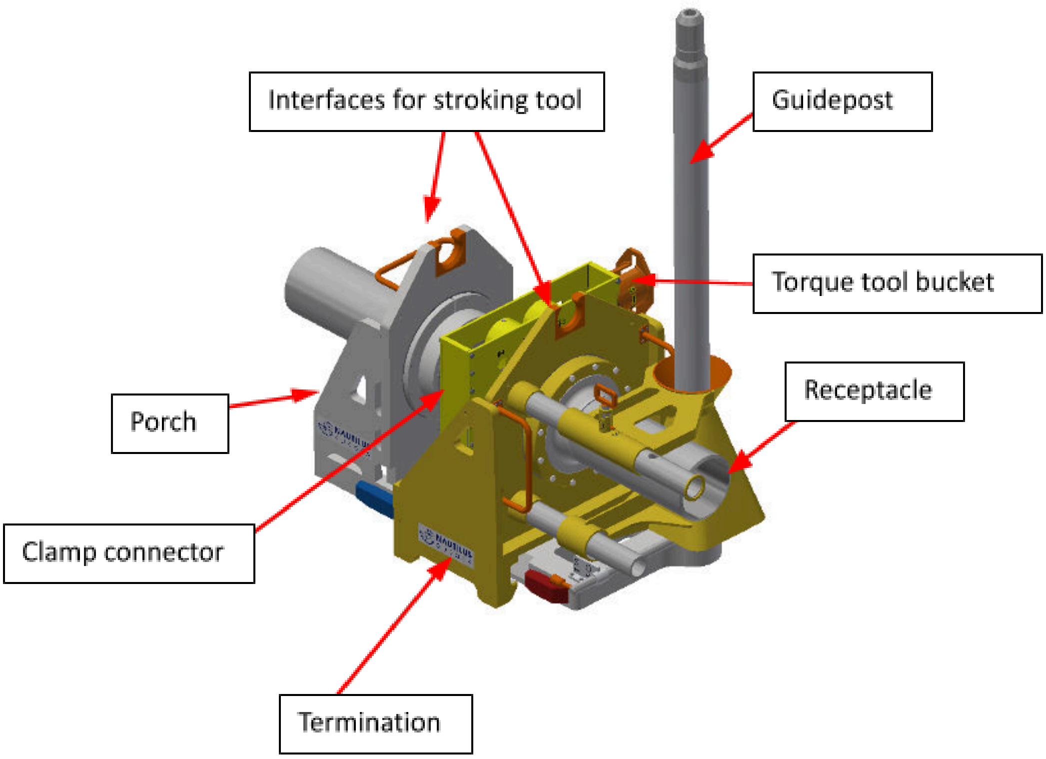


Figure 2-1 Horizontal tie-in system

3 Swivel and yoke

The swivel is field-proven and comprises of:

- Two-part swivel
- Yoke
- Position transducer
- Compass
- Leakage monitoring

The main features of this unit are:

- The mooring forces from the shuttle tanker through the offloading hose are taken by the yoke and transferred to the lower part of the swivel assembly, the mooring swivel.
- The fluid swivel, upper part, does not experience any mooring forces and is rotated by a non-rigid arm and no bending moments are transferred except for a small addition from the first hose.
- The swivel is of a pressure balanced, toroidal design. This gives no end-cap effect and the rotating moment is relatively low.
- Special spring (O-ring) activated Bronze rings acts as ingress protection for sand and other pollution into the sealing system. This is a technology taken from hydro power turbines used in areas where there is sand in the water supply.

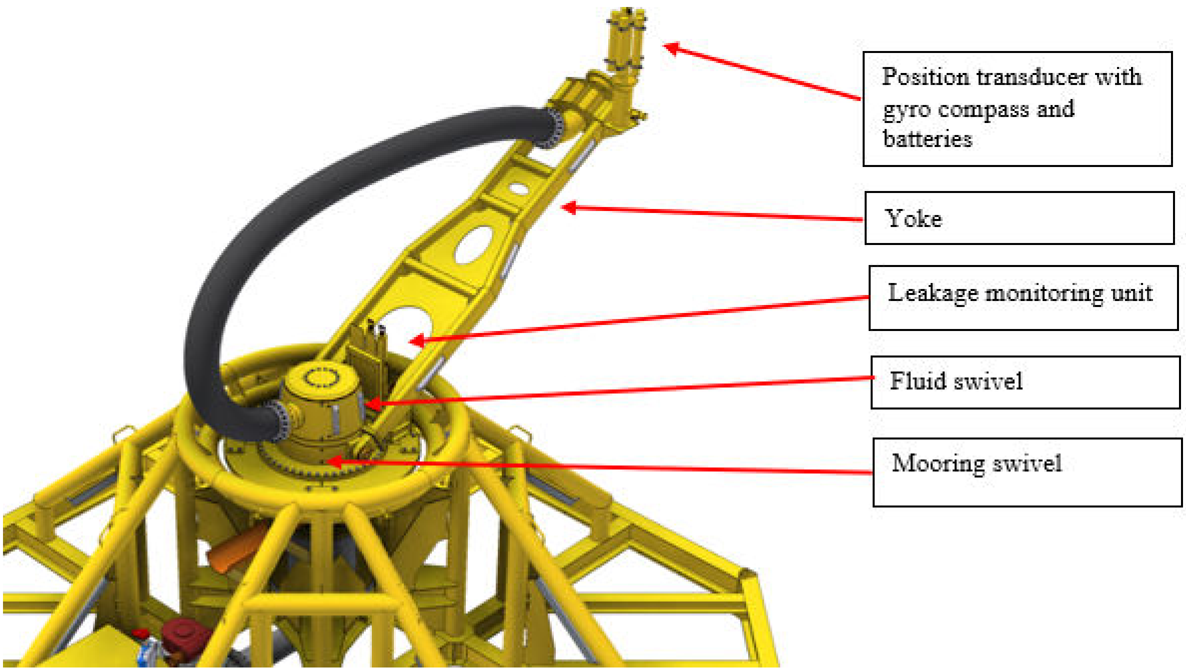


Figure 3-1 Swivel

4 Gravity base steel structure

The Gravity Base Structure comprises the following main components:

- Main steel structure
- Piping arrangement including ball valve
- Horizontal tie-in point with clamp connector and seal
- Vertical alignment and tie-in assembly w/clamp connector and seal
- Concrete dead weights (4 off)

The steel structure has the following key functional purposes:

- Vertical landing base for riser
- Vertical and horizontal support for riser loads.
- Horizontal tie-in support point for flowline/export line.
- Support for transponder array to locate offloading system.

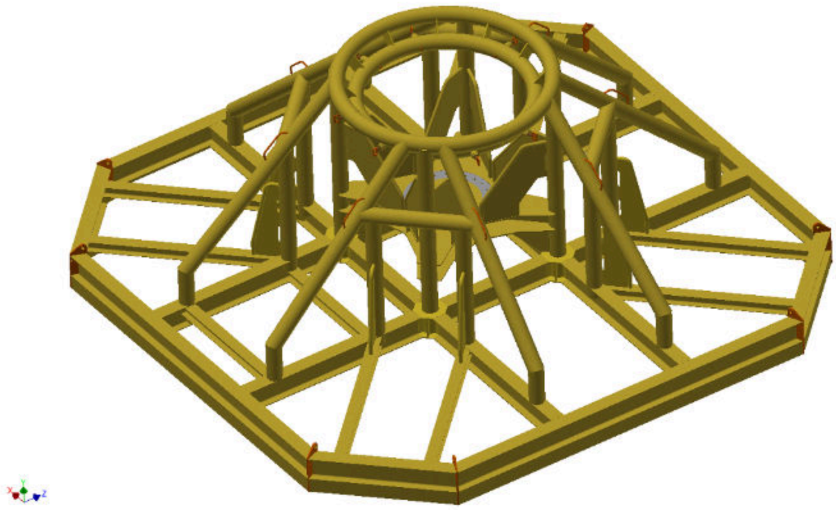


Figure 4-1 Main steel structure

The frame is prepared for installation of dead weights, either as clump weights or rock dump. The support frame can be fitted with skirts for increased capacity for shear loads.

There will be support points for a transponder array.

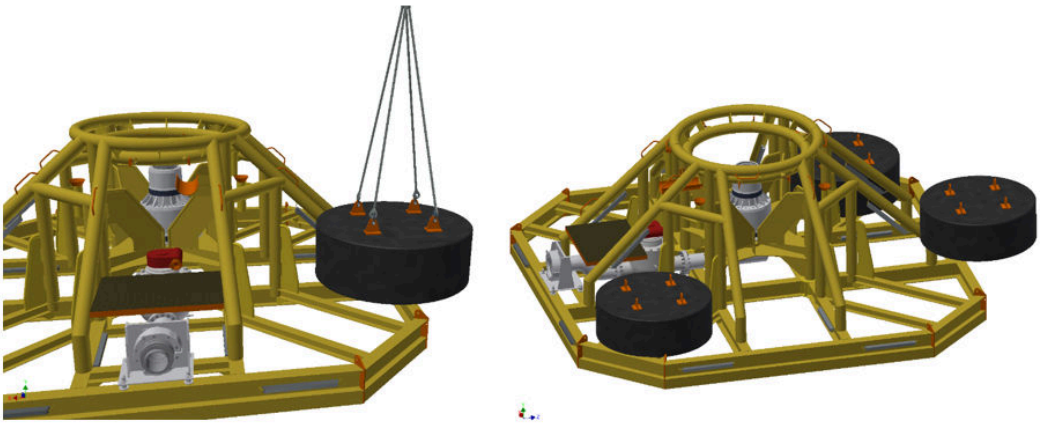


Figure 4-2 Model with clump weights

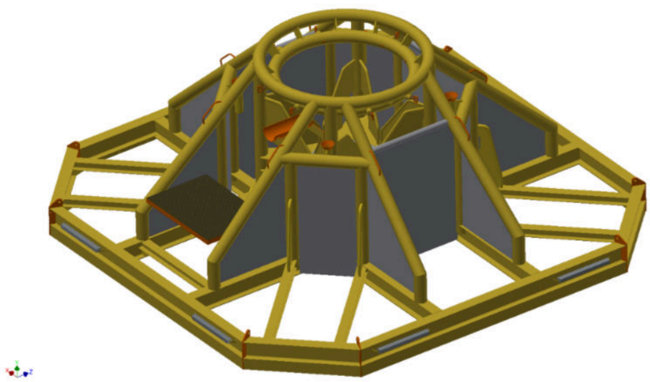


Figure 4-3 Main frame prepared for rock dump

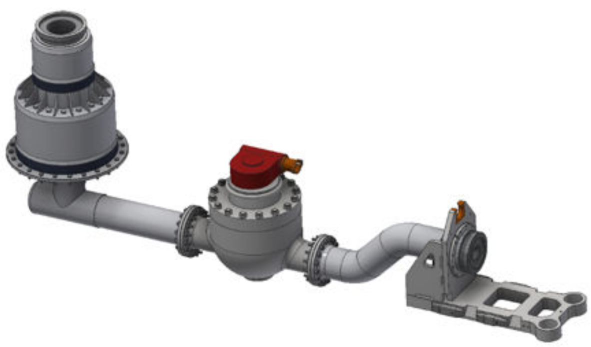


Figure 4-4 Internal piping with valve.

5 Riser assembly

The riser assembly comprises of:

- Hose. Can be continuous or consist of 12m joints
- Hose end valve for connection to off-loading system on tank deck
- Transponders, transducers and compass
- Buoyancy elements for a lazy s configuration
- Heavy spool pieces
- Can come with a marine breakaway coupling. This may not be required.
- The system may come with an installation spread, this applies for the jointed hose

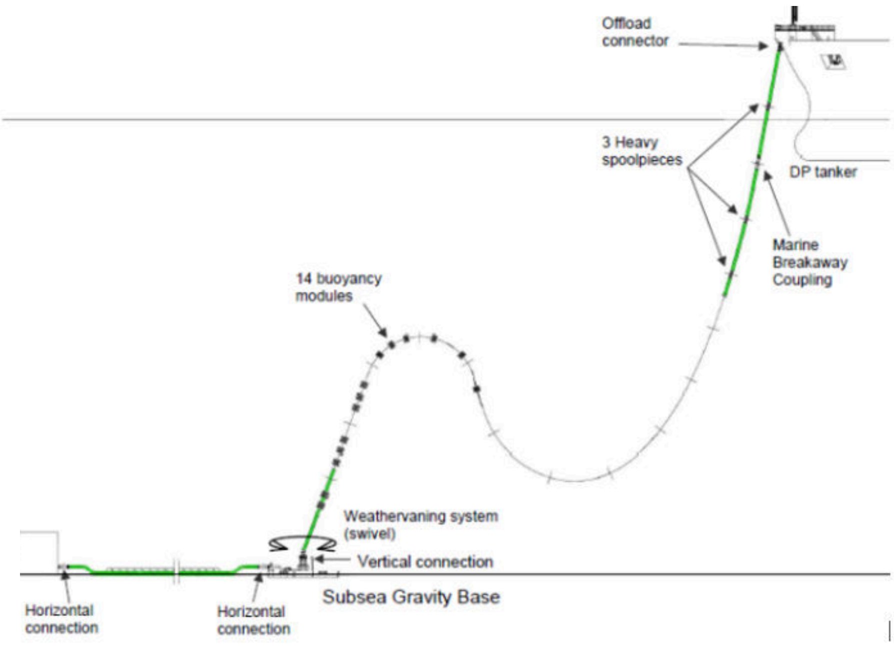


Figure 5-1 Riser

The riser can either be a continuous hose or consist of 12m joints. The latter option can come with a complete installation spread for installation over the vessel side. This option will thus not require a vessel with reel capacity.

The riser comes with buoyancy elements and heavy spool pieces for correct configuration of the riser both under off-loading and during wet storage on seabed.

It will have a hose end valve (HEV) for connection to the vessel off-loading system. A transducer is mounted to the HEV.

6 Vertical tie-in arrangement

The vertical tie-in system comprises of:

- Guiding and support system
- Clamp connector
- Seal

The vertical tie-in system comes with a guiding system that also acts like a permanent support. Bending moments and shear loads from hydrodynamic and operational loads are taken by the support.

The clamp connector has a double acting seal preventing both leakage and external contamination of the oil or gas.

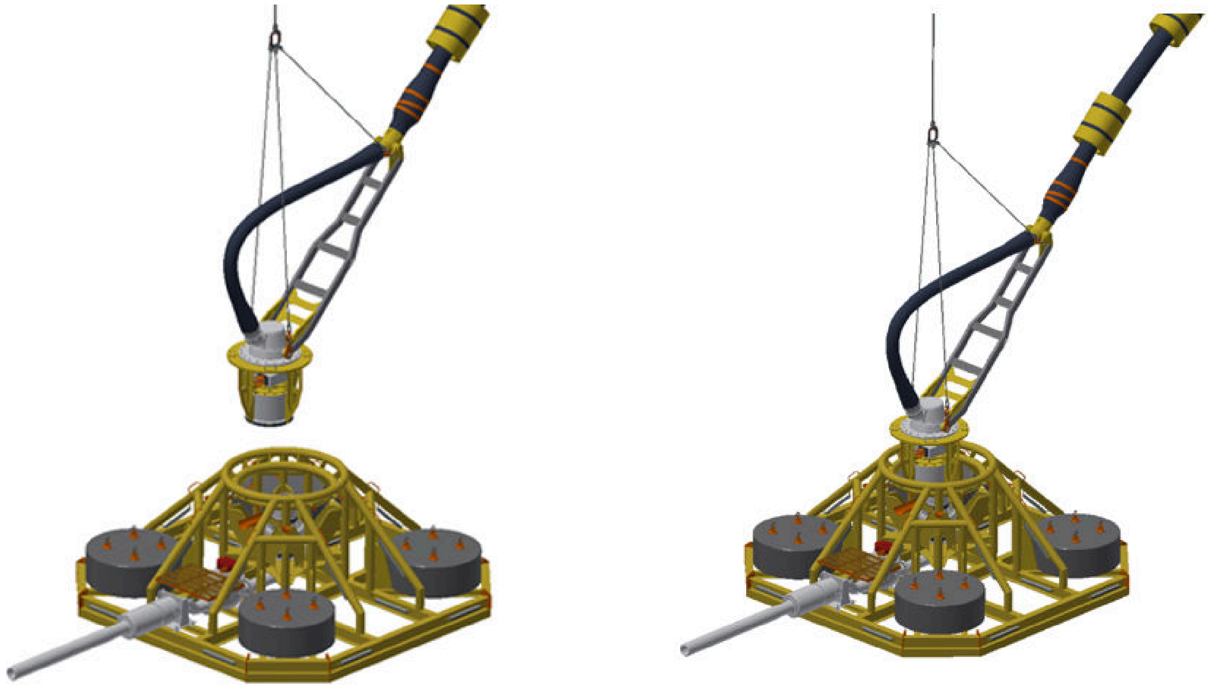


Figure 6-1 Installation of vertical tie-in system

7 Messenger line arrangement

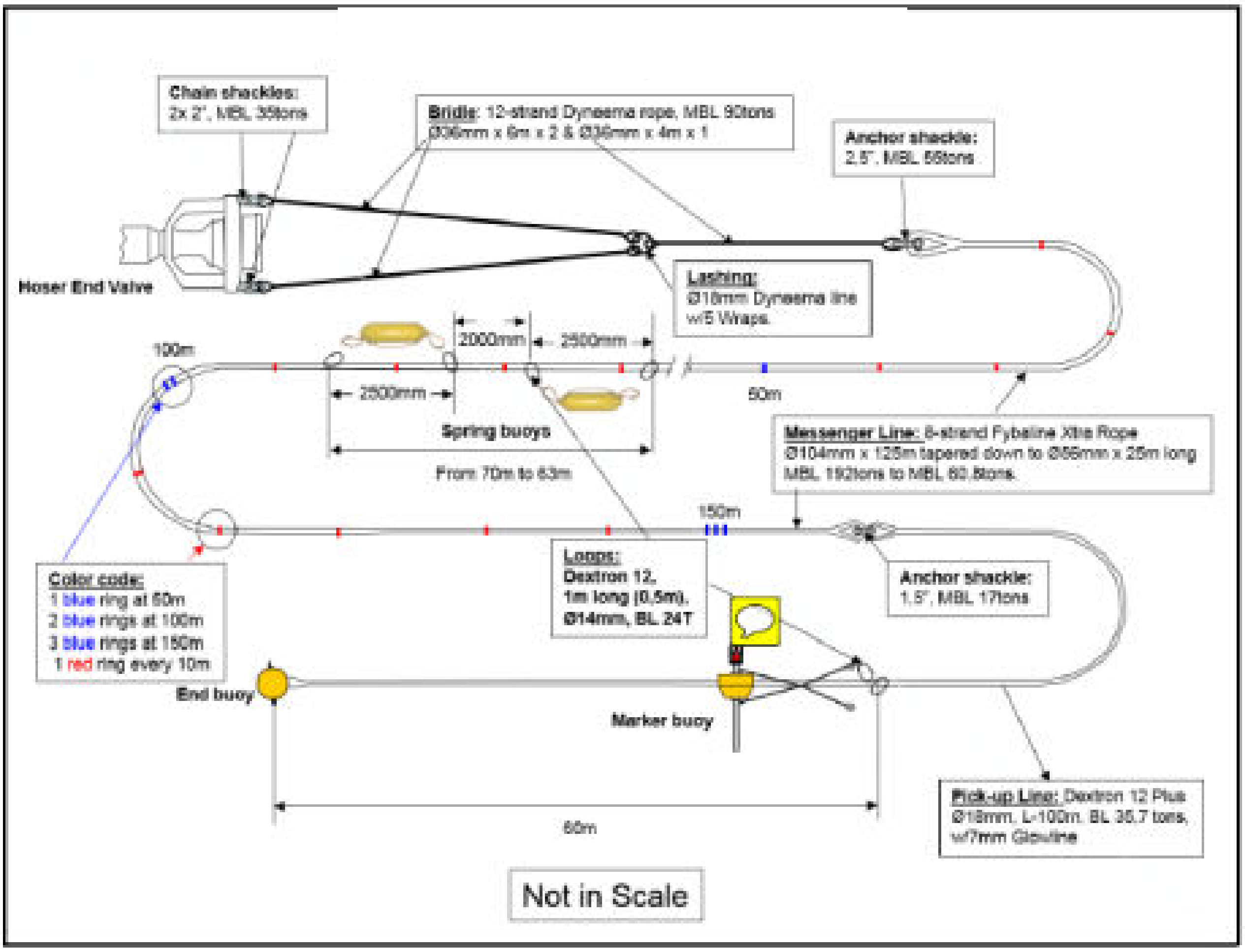


Figure 7-1 Schematics of messenger line

The messenger line is attached to the HEV and comes with a radar and pick up buoy and is designed according to the prevailing standars.

8 Positioning and communication system

The positioning system has the following components:

- Transducers mounted on the swivel and HEV
- Fiber optic compass mounted on the swivel
- Transponder array mounted on the main steel frame
- Battery package for minimum 2.5 years operation

A transducer and a compass are mounted on the yoke. Another transducer is mounted on the HEV. The transponder array is installed on the main steel structure. This system will on command acoustically transmit the heading data to the positioning system on board the tanker.

There is no need for installing a transponder array on the seafloor.

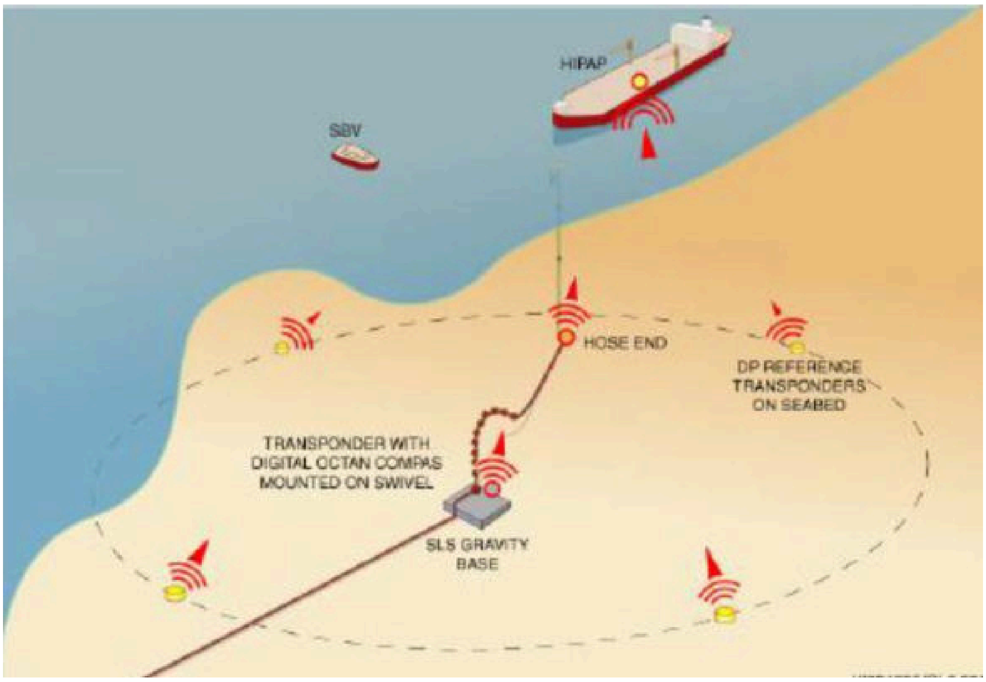


Figure 8-1 Typical transponder array. For the SLS there will not be necessary to install the transponders on the seabed.

9 Riser installation and replacement methodology – jointed hose

9.1 Summary

A preliminary installation methodology for the riser has been established, backed by OraFlex analysis in order to visualize and check the feasibility of the proposed design. This outline does not cover the installation of the Gravity Base Structure (GBS) or the pre- and post- survey of the installed system.

A generic light construction vessel (LCV) was modelled, with the crane pedestal and the vertical assembly platform on the same side of the vessel. The riser deployment location is located close to the vessel midline to reduce vessel induced motion response into the riser.

The installation has been analyzed statically in OrcaFlex. A few dynamic checks of critical phases of the operation has been performed, but a full dynamic analysis will be performed during the detail engineering phase of the project planning with the correct RAOs.

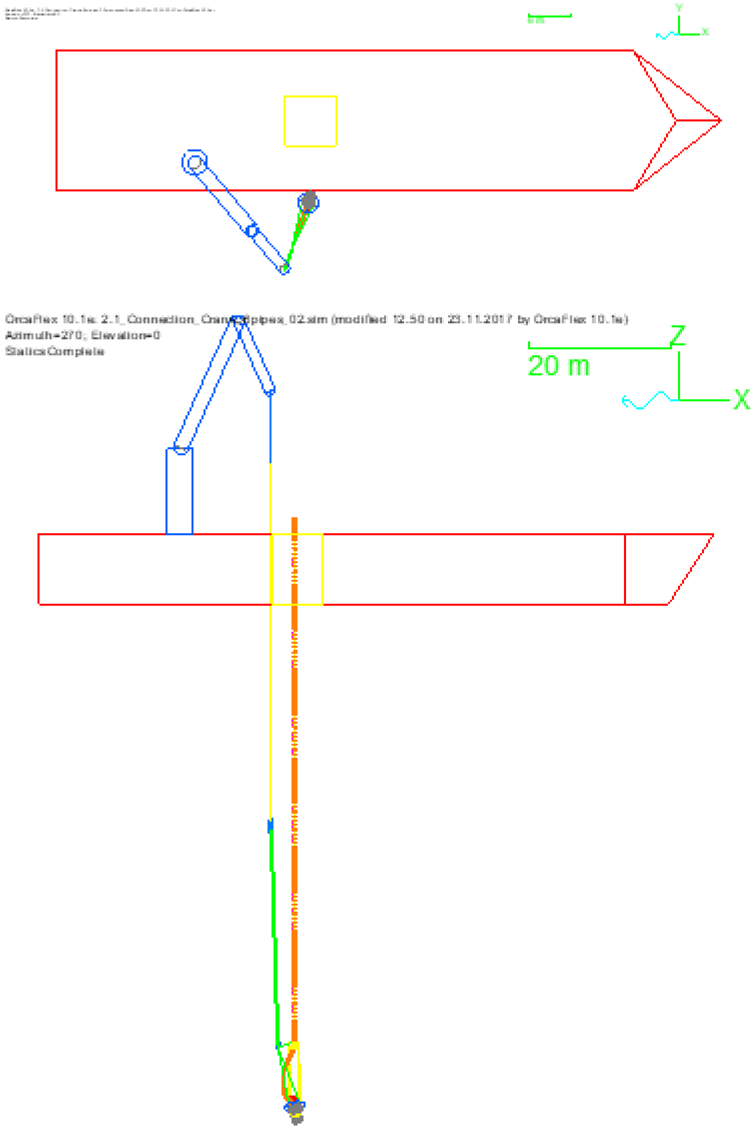


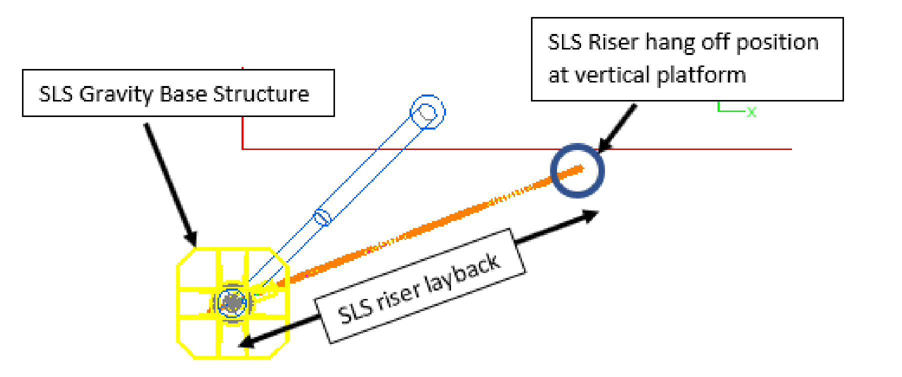
Figure 9-1: Illustration of a generic LCV with the crane and the proposed deployment setup.

Vessel crane capacities

To be able to execute the SLS riser installation the vessel should have the following crane capacities:

Table 9-1: Installation vessel required crane capacities.

	Properties	Unit	Value
1	Crane capacity (SWL) to establish min 40 m layback from the vertical assembly platform.	Te	40

			
2	A secondary crane to lift the Trelline hoses from storage location to the horizontal preparation station and further to the vertical assembly platform.	Te	3.0
3	An ancillary crane with capacity (SWL) to deploy the Trelline riser through the vertical assembly platform. (this may be the same crane as requirement 2)	Te	20 (at the platform)

9.2 OrcaFlex illustration

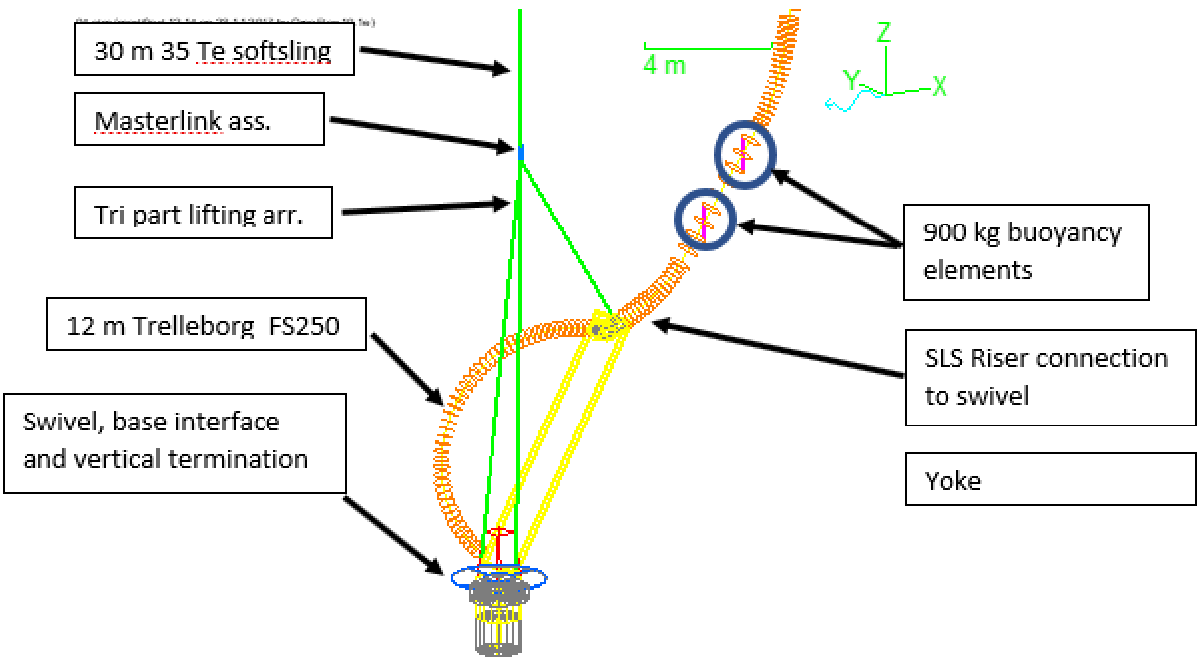


Figure 9-2: Illustration of the modelled swivel and riser connection

9.3 Deck handling

The deck preparations and handling is proposed performed in accordance with the method used on the previous installation of the Yme riser, described in Assembly Report 01.39420.0073 rev

00. The hoses will be lifted from storage to a horizontal work station on deck where they will be prepared. Several stations will be set up, which permits for parallel processes. The hose will be lifted to the vertical platform and installed on the previous hose section.

9.4 Subsea operations

The following sections provides an outline of the methodology proposed for installation of the YME SLS riser. The method assumes that the Gravity Base Structure (GBS) has been installed and ready to be connected to the SLS riser.

9.4.1 Riser and crane wire deployment

A sensitivity study of the riser and crane wire (for the swivel) deployment location has been performed. Three configurations has been analyzed; same side (riser and crane wire), moonpool and opposite. The conclusion is that the crane wire and riser should be deployed on the same side of the vessel. This setup reduces the risk of riser-vessel contact during the establishment of hog/sag phase of the operation.

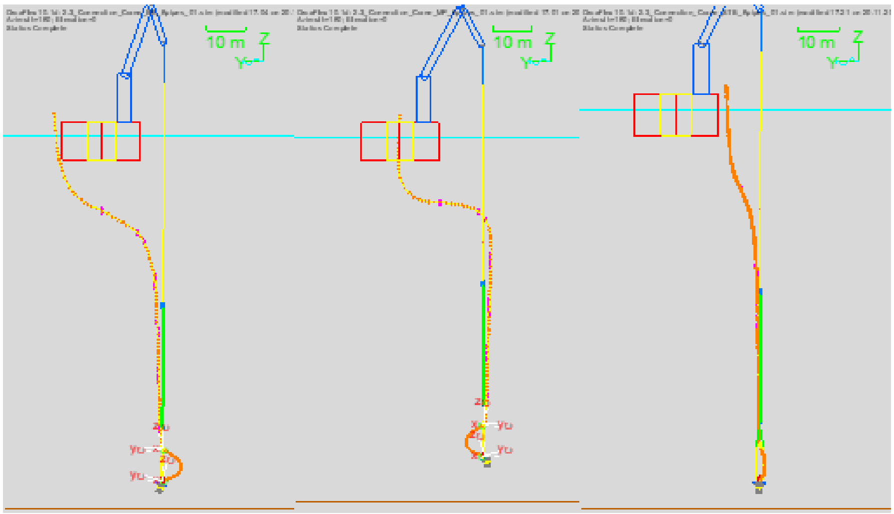
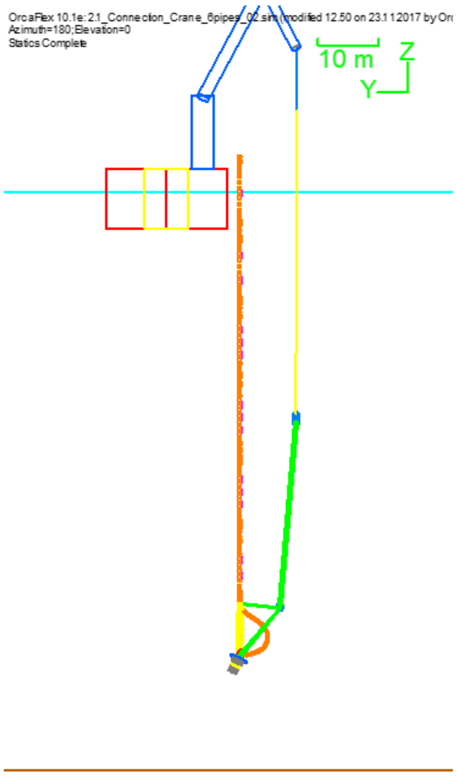
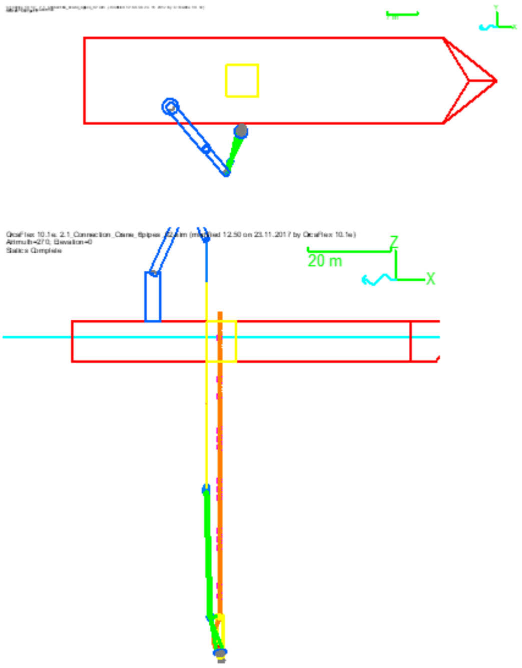
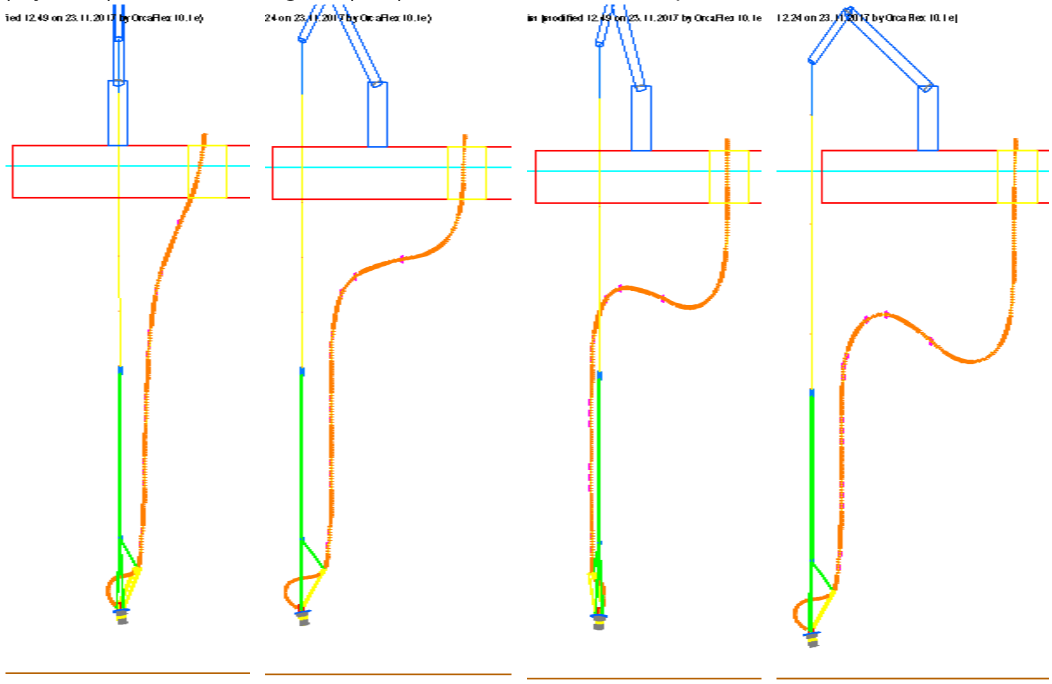


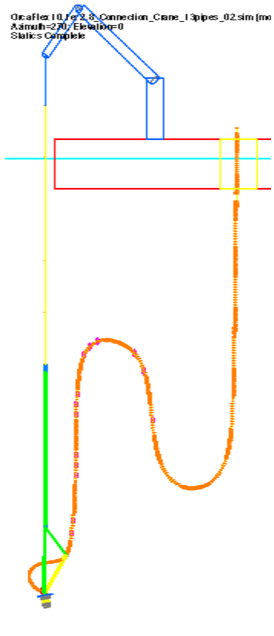
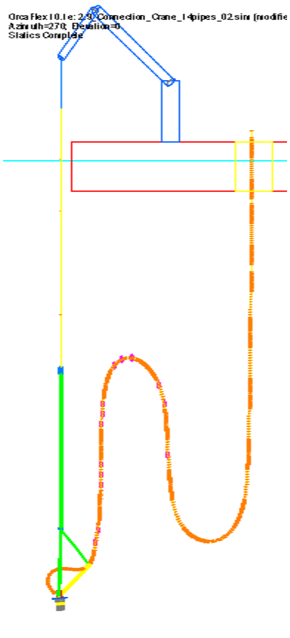
Figure 9-3: Illustration of the riser configuration in the early phase of the hog/sag establishment.

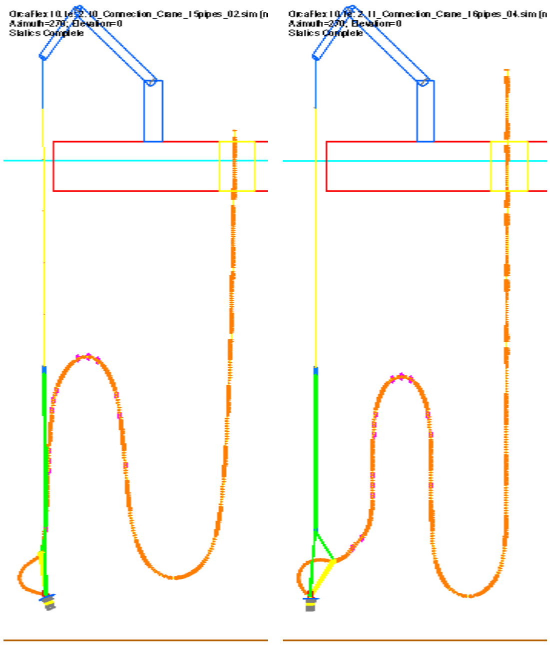
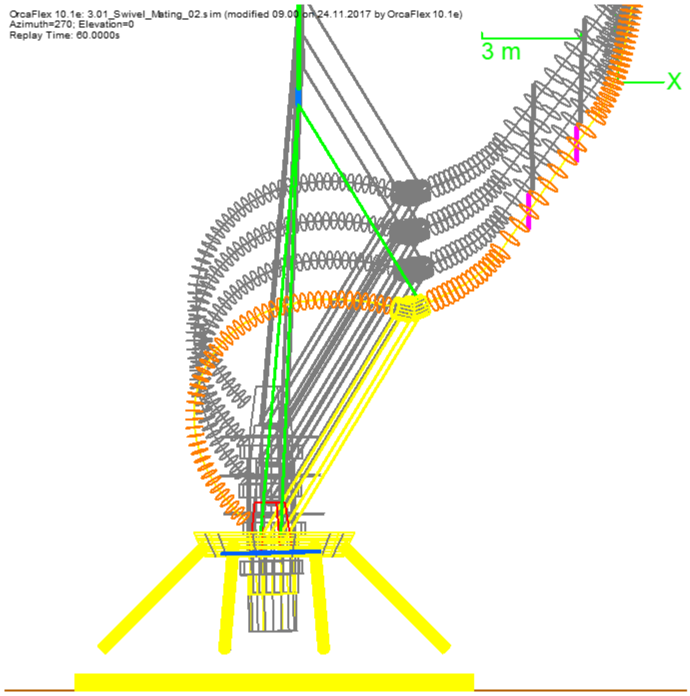
This study was motivated to increase the riser layback and thus reduce the risk of overbending the riser in the hog and sag sections.

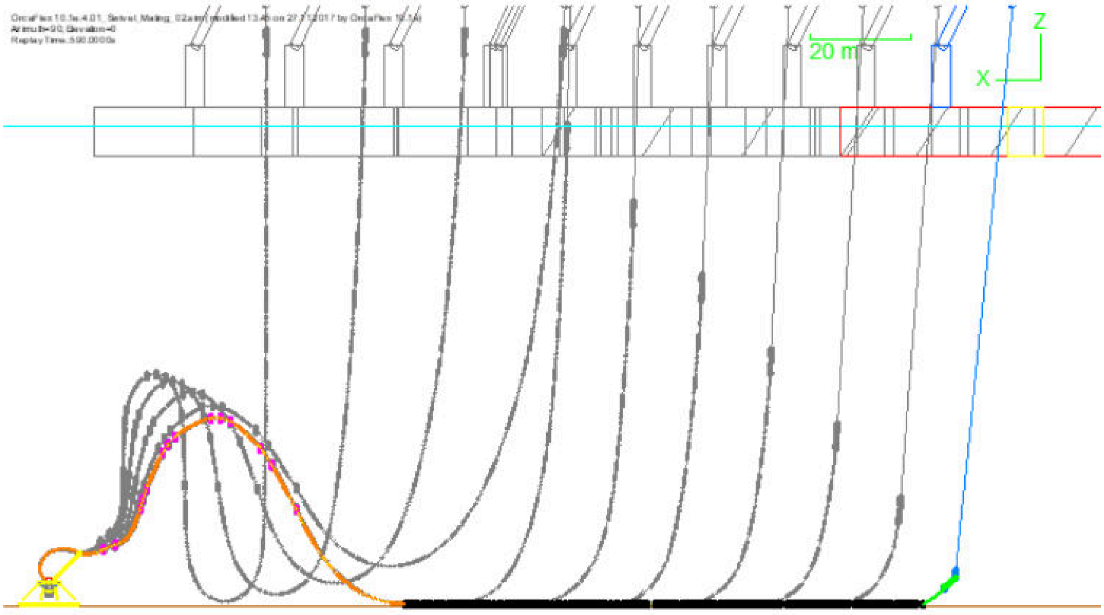
9.4.2 Riser installation

Task ID	Task Description
1	Position the installation vessel in a safe area (dropped objects). Install and deploy 6 pipes and the swivel, then deploy the main crane with the swivel tri part rigging and connect rigging to the swivel. After this step the ancillary crane must be used to deploy the riser through the vertical platform.

	 
2	Continue to install and deploy hoses. Slew the crane clockwise to establish separation (layback) between hang off (HO). This will reduce compressional waves in the riser. 

3	Finalise the riser building with the last hose connected at the vertical assembly platform. For deploying hose no 15, the ancillary crane must have an SWL capacity of approx. 15 Te at the vertical platform.    

	 Note: The swivel is ready to be mated with the GBS when the last hose is installed, the top end is deployed after the swivel is installed at the GBS. This is to maintain an acceptable seabed clearance at the riser sag bend.
4	Relocate the vessel to the GBS to mate the swivel with the RGB with the vessel crane in AHC-mode. When the mating of the termination has been confirmed complete, disconnect the swivel from the main crane and recover the crane wire to deck. 
5	Install messenger wire on the riser topside end.
6	Connect the main crane to the riser top end, and stepwise increase layback. One ROV to monitor the sag bend. Start deploying the riser according to the step table. Land the riser

	with sufficient layback, one ROV to monitor the touchdown during landing. Lay the remaining riser. Increase layback during landing of the topside end. 
7	Disconnect the crane and recover to deck.

9.5 Dynamic response

Some preliminary dynamic sensitivity check has been performed in the tender phase. The simulation has been performed with the full length of the riser installed, and hung off in the vertical platform on the 15th hose (second to last hose). The dynamic results are highly dependent on the vessel specific RAOs, and should only be used as a rough estimate of the expected dynamic response. Also, only two wave periods have been analyzed, and during detail engineering phase the analysis should be performed over the relevant wave periods.

<u>3 hours storm; Hs 3.0 m Tp 12 s 15 deg</u>

A 3-hour, Hs 3.0 m Tp 12 s 15 deg wave heading has been simulated. The analyzed vessel has a roll peak period is at 12.5s for 15 deg waves.

Table 9-2: 3 hr storm check results

Parameter	Unit	Value	Limit
Max dynamic crane load	[kN]	688	n/a
Min dynamic hook load	[kN]	145	33.9, *10 % Static load*
SLS Riser Normalised curvature	[-]	0.8	1.0
SLS Riser max dynamic tension	[kN]	235	600

SLS Riser min dyn tension	[kN]	-144	Unknown
Max bending moment end pipe	[kN.m]	34.0	n/a

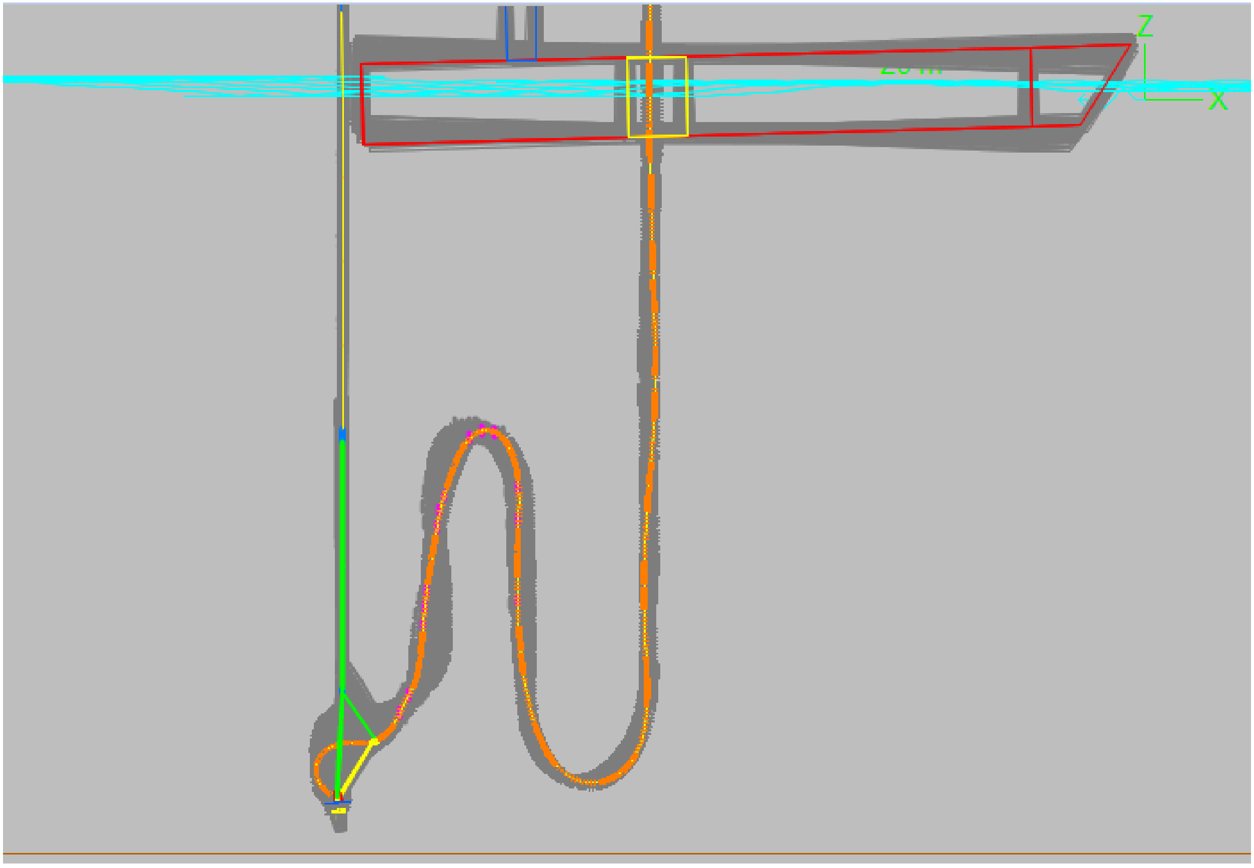


Figure 9-4: Dynamic response of the riser system hung-off at the vertical platform.

The proposed concept will also provide a certain protection against impact loads from fishing equipment.