PETROBRAS	**TECHNICAL SPECIFICATION**	**Nº:** I-ET-0000.00-0000-274-P9U-002	
	CLIENT: PETROBRAS		**SHEET:** 1 **of** 39
	JOB:		CC
	ÁREA:		PROJECT:
ENGENHARIA	**TÍTLE:** **TECHNICAL SPECIFICATION FOR FSHR**		
			GESTOR: EIES / EIS

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INDEX OF REVISIONS

REV.	**DESCRIPTION AND/OR REVISED SHEETS**
0	**ORIGINAL** This document supersedes and replaces document I-ET-0000.00-6500-274-PPR-001, rev. F.

	REV. 0	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G	REV. H
DATE	30/11/2017								
PROJECT	EISE/EDR								
EXECUTION	BF7D								
CHECK	BF6I								
APPROVAL	CLZ2								

1. INTRODUCTION

1.1. GENERAL SCOPE AND APPLICABILITY

This technical specification describes the main design inputs, states the minimum technical requirements, outlines the design methodologies and lists the main deliverables for each analysis of the Detailed Engineering and Final Design of FSHR system.

CONTRACTOR shall comply with all requirements in this Technical Specification. Further information about the PETROBRAS service requisition is described in other contractual documents. Any discrepancy between documents shall be submitted to PETROBRAS for clarification.

If any aspect of this technical specification is not clear, CONTRACTOR shall liaise with PETROBRAS in order to clarify the associated requirement.

1.2. GLOSSARY

The following definitions are used for the purpose of this specification:

PETROBRAS	Petróleo Brasileiro S.A.
CONTRACTOR	The Company responsible for the design and analysis of the FSHR.
Shall	Mandatory requirement.
Should	Recommended requirement as good practice, but not mandatory.
May	Optional, on course of action.
Installation	Used in this document to refer to all operations for FSHR installation, including load out to sea and transportation to site
Overpull	Effective tension at the riser base
Tidal variation	The alternate rising and falling of the surface of the ocean caused by gravitational attraction of the moon and sun.

1.3. ABBREVIATIONS

AFF	Additional Fatigue Factor
BT	Buoyancy Tank
CFD	Computational Fluid Dynamics
FAT	Factory Acceptance Test
FEA	Finite Element Analysis
FEM	Finite Element Method
FPSO	Floating Production Storage and Offloading
FPU	Floating Production Unit
FSHR	Free Standing Hybrid Riser
LRA	Lower Riser Assembly
OD	Outside Diameter
RAO	Response Amplitude Operator
SCF	Stress Concentration Factor
SI	International System of Units
SJ	Stress Joint
SS	Semi-Submersible Unit
SUT	Subsea Umbilical Termination
URA	Upper Riser Assembly
VIM	Vortex Induced Motion
VIR	Vortex Induced Rotation
VIV	Vortex Induced Vibration

1.4. FSHR SYSTEM CONFIGURATION

The Free Standing Hybrid Riser concept consists of a vertical rigid steel riser and a flexible jumper. The rigid section is anchored at the seabed and supported by a Buoyancy Tank. The flexible jumper connects the Upper Riser Assembly to the Floating Production Unit. The main advantage is to significantly decouple the movements of the FPU and Riser in order to improve fatigue life. This system is applicable for production, injection and export of oil and gas.

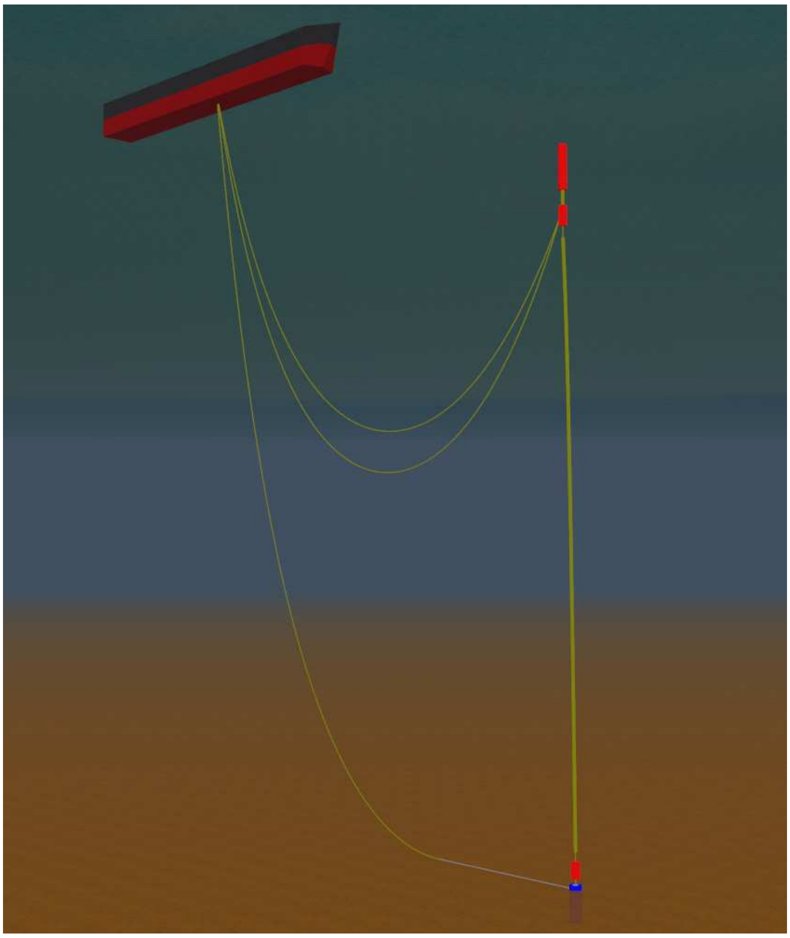

Figure 1.4.1 – FSHR concept

2. REFERENCES

2.1. GENERAL

Detailed Engineering Design of the FSHR system shall be performed in accordance with requirements of the rules and codes listed herein.

CONTRACTOR shall consider the latest revision of the following design codes.

In the case of conflict between the requirements of this specification and the requirements of the referenced codes and standards CONTRACTOR shall consult PETROBRAS to resolve the issue. Generally the most stringent requirement shall apply to the design.

2.2. INDUSTRY CODES, STANDARDS AND SPECIFICATIONS

[1] DNV-OS-C201	Structural Design of Offshore Units (WSD Method)
[2] DNV-OS-F201	Offshore Standard, Dynamic Risers
[3] DNV-OS-F101	Offshore Standard, Submarine Pipeline Systems
[4] DNV-OS-C101	Design of Offshore Steel Structures, General (LRFD Method)
[5] DNV-RP-C201	Buckling Strength of Plated Structures
[6] DNV-RP-C202	Buckling Strength of Shells
[7] DNV-RP-C203	Fatigue Strength Analysis of Offshore Steel Structures
[8] DNV-RP-C207	Statistical Representation of Soil Data
[9] DNV-RP-E303	Geotechnical Design and Installation of Suction Anchors in Clay.
[10] DNV-RP-F203	Riser Interference
[11] DNV-RP-F204	Riser Fatigue
[12] API RP 2RD	Design of Risers for Floating Production Systems (FPSs) and Tension-Leg Platforms (TLPs)
[13] API RP 1111	Design, Construction, Operation and Maintenance of Offshore Hydrocarbon Pipelines (limit state design)
[14] API RP 2A-WSD	Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design
[15] API RP-2R	API Recommended Practice for Design, Rating, and Testing of Marine Drilling Riser Couplings
[16] API RP-2T	Recommended Practice for Planning, Designing, and Constructing Tension Leg Platforms
[17] API Spec – 17J	Specification for Unbounded Flexible Pipe

[18] DNV-RP-B401	Cathodic Protection Design
[19] API 5L / ISO 3183	Specification for Line Pipe
[20] ASME Boiler and Pressure Vessel Code – Section VIII	Rules for Construction of Pressure Vessels – Division 2 – Alternative Rules
[21] ASME B31.8	Gas Transmission and Distribution Piping Systems
[22] ISO 9001	Quality Management Systems
[23] NACE MR0175	Sulphide Stress Cracking Resistant Metallic Materials for Oilfield Equipment
[24] DNV - Marine Operations	Rules for Planning and Execution of Marine Operations – Part 2, Chapter 5: Lifting
[25] AWS D1.1/D1.1M	Structural Welding Code - Steel

2.3. PETROBRAS TECHNICAL SPECIFICATIONS AND STANDARDS

[26] I-ET-3A26.00-5529-850-PPC-001	Decoupled Riser (FSHR) Monitoring System for Lula N and ES
[27] I-ET-3010.92-5529-850-PPC-001	Riser Monitoring System (RIMS)
[28] I-ET-3010.92-5537-850-PPC-001	Positioning System (POS) for Offset Diagram
[29] ET-3500.00-1516-273-PSE-062	Requisitos para Swivel Submarino
[30] ET-3500.00-1510-224-PPC-001	Válvula Esfera Submarina
[31] I-ET-3A29.00-6500-274-PPC-002	Flexible Pipe Jumpers and Umbilicals
[32] ET-3000.00-1514-270-PAZ-001	Sistema de conexão direta com pescoço de ganso
[33] ET-3000.00-1500-251-PAZ-001	Fixadores em Aço de Alta Resistência para Utilização Submarina
[34] ET-3000.00-1500-251-PAZ-002	Rastreabilidade de Fixadores de Aço de Alta Resistência para Utilização Submarina
[35] I-ET-0000.00-6500-966-PPR-001	Pipelaying Analysis
[36] N-1852	Estruturas Oceânicas - Fabricação e Montagem de Unidades Fixas

2.4. QUALITY ASSURANCE

Engineering design shall be performed using a quality assurance system in compliance with ISO 9001 (Ref. [22]).

3. DESIGN PRINCIPLES AND LOADING CONDITIONS

3.1. GENERAL

FSHR systems shall be designed in accordance with the design principles described in this section.

All information and requirements, applicable rules and codes, etc. contained herein aim to provide guidelines for the detailed engineering design of FSHR systems. CONTRACTOR shall consider more stringent requirements if necessary.

The unit system for design shall be the SI.

Pipe diameters may be specified in inches but SI dimensions shall also be given.

3.2. DESIGN CODES

The component design shall be performed according to the design codes listed in this section. For fabrication codes refer to the respective fabrication documents. Additional codes are provided in the specific sections of each component.

Section	Component	Design Code
3.2.1.	BT	The pressure containing compartments: Ref. [20]; The structural components: Ref. [1], [5] and [6];
3.2.2.	Tether Bar	The structure design: Ref. [4];
3.2.3.	URA	The structure design: Ref. [1] , [5] and [6]; The pipe bends: Ref. [21]; Straight pipe sections: Ref. [2] and [3];
3.2.4.	Connectors and MCVs	Minimum requirements for connectors and MCVs: Ref. [32]; Minimum requirements for swivels of the MCVs: Ref. [29];
3.2.5.	Monitoring System	Minimum requirements: Ref. [26], [27] and [28];
3.2.6.	Stress Joints	The structure design: Ref. [2] and [20];
3.2.7.	Rigid Pipe Section	The Detailed Engineering Design: Ref. [2] and [3];
3.2.8.	LRA	The structure design: Ref. [1] , [5] and [6]; The pipe bends: Ref. [21]; Straight pipe sections: Ref. [2] and [3];
3.2.9.	Rotolatches	Minimum requirements for flexible joints design: Ref. [2] and PETROBRAS minimum requirements. Ref. [12] may be used when Ref. [2] is not applicable or silent.
3.2.10.	Foundation	The foundation analysis: Ref. [8] and [9]; The structure design: Ref. [1] , [5] and [6];
3.2.11.	Bolts and Nuts	Minimum requirements: Ref. [33] and [34];
3.2.12.	Pre-commissioning	Minimum requirements for performing the pre-commissioning: Ref. [2] and [3]; Minimum requirements for pre-commissioning valves: Ref. [30].

Note: Sructural welds and inspection of components shall comply with requirements of Ref. [25] and [36] with materials requirements of Ref. [14].

3.3. ENVIRONMENTAL CONDITIONS AND DESIGN LOADS

3.3.1. Environmental Conditions

All system conditions in accordance with the specific functional and operational requirements of the FSHR system shall be considered for the detailed design of FSHR. The environmental conditions presented in Table 4.3.1 should be used in analyzing the design cases outlined in Table 4.3.3 for the various loading categories (Operating, Extreme, Temporary, Fatigue, Accidental, Survival).

Environmental condition	Description (1)	Return period (years)		
		Current event	Wave event	Wind event
# 1	Extreme – Current	100	10	10
# 2	Extreme – Wave	10	100	100
# 3	Extreme – Wave only	---	100	100
# 4	Max. Operating – Current	10	1	1
# 5	Max. Operating – Wave	1	10	10
# 6	Max. Operating – Wave only	---	10	10
# 7	Extreme-Wind & Wave opposing surface current (2)	10	100	100

[1] FPU offset, surface current and waves are all in the same direction, apart from # 7.

[2] FPU offsets, wind and waves applied in the same direction. Surface currents, in opposing direction

Table 4.3.1 – Environmental conditions

3.3.2. Design Loads

All loads acting on the FSHR system that may be found during the design life and for all system conditions shall be identified and shall be considered within suitable safety margins in the design and analysis of the FSHR. Main design loads include all design loads as defined in [2], section 3.

Each line of Table 4.3.3 contains a set of environmental conditions according to table 4.3.1. For each of these environmental conditions 16 different incidence directions shall be considered according to Figures 4.3.1 and 4.3.2, defining a load case. When a FPSO is the chosen floating unit, all load cases shall be evaluated considering at least three different drafts of the FPU.

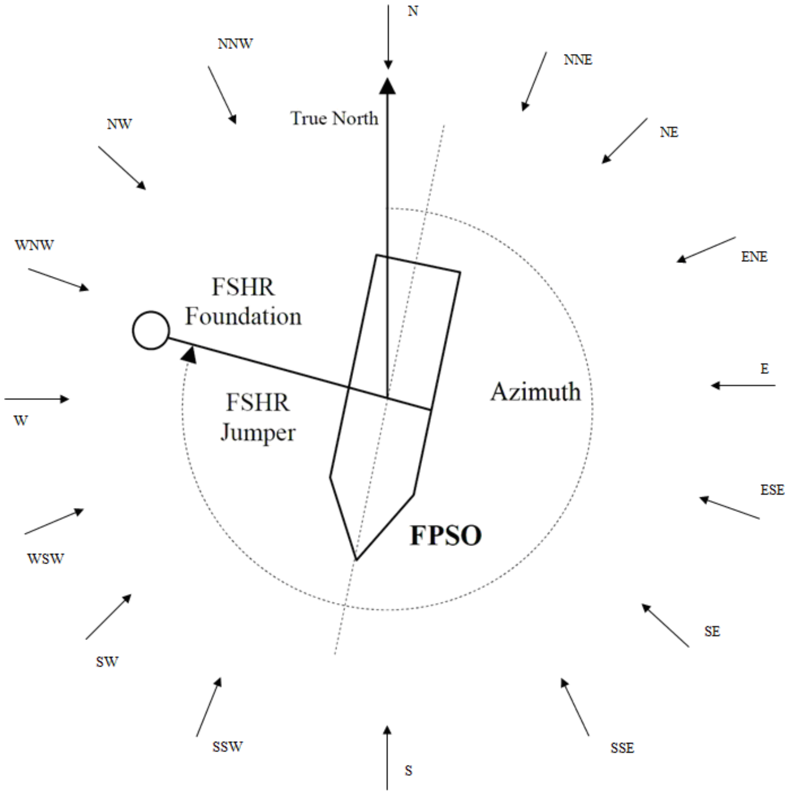

Figure 4.3.1 – Incidence directions to be considered for waves

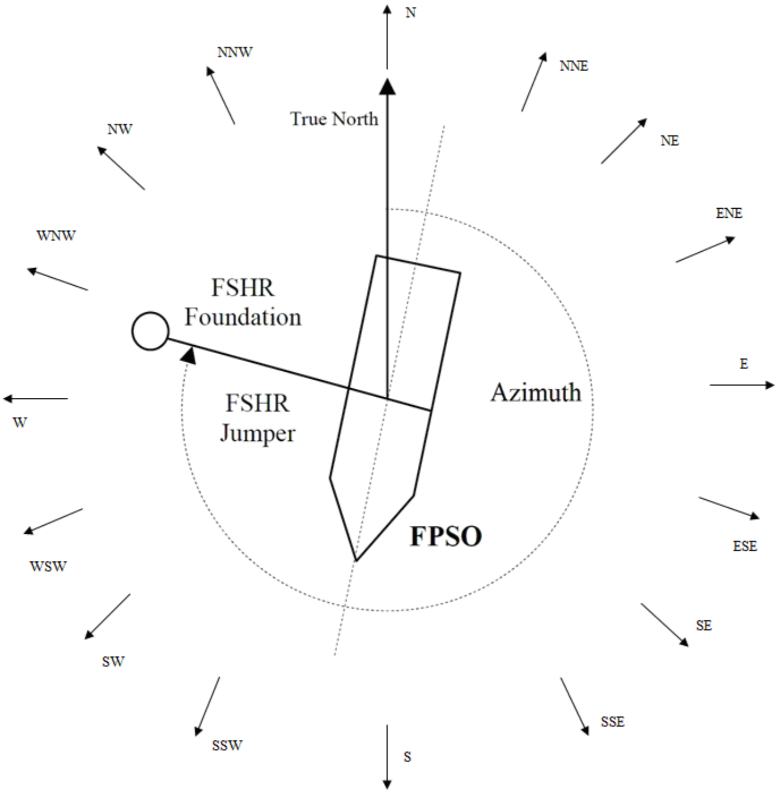

Figure 4.3.2 – Incidence directions to be considered for current

At least, the following accidental events shall be evaluated:

- One mooring line broken;
- Flooding of buoyancy tank compartments (cases and acceptance requirements are described in Section 6.2);
- FPU accidental heel and trim angles according to Table 4.3.2;
- Internal fluid overpressure (incidental pressure);
- Free hanging flexible jumper at the URA[1];

Note 1: Two cases shall be analyzed: 1) Free hanging flexible jumper case considering the dynamic loads imposed at the URA by the free fall of the jumper. 2) The static condition considering the flexible jumper hanging at the URA.

For both cases CONTRACTOR shall perform analyses to determinate the flooding condition of the FSHR considering the temperature and pressure variation.

CASE	FPU	Heel	Trim
1	FPSO	$+\alpha$	0
2	FPSO	$-\alpha$	0
3	SS	$+\alpha$	$+\alpha$
4	SS	$+\alpha$	$-\alpha$
5	SS	$-\alpha$	$+\alpha$
6	SS	$-\alpha$	$-\alpha$

Table 4.3.2 – Heel and Trim angles

Where α depends on the FPU.

Contractor shall identify if there are any relevant cases that are mentioned above and inform PETROBRAS. These cases shall be included in the analysis as well.

3.3.3. Impact of external and internal pressures variations on the BT

The following mechanisms shall be considered for the BT design:

- Risers' contraction or expansion due to its internal fluid temperature variation, causing variation of the BT installation depth and thus variation of the external pressure on BT compartments;
- Seawater temperature variation in the vicinity of BT and its impact on the compartments' internal pressure. Since these compartments are isolated from the external environment, temperature variation of the internal gas causes variation of the internal pressure (P.V = n.Z.R.T). Questions related to the gas injection temperature above the water line, where it is captured, shall be

considered. Care shall be taken regarding the difference of temperature to which the internal gas may be subjected between the filling stage and a given extreme event moment, particularly the difference that may happen after heat exchange due to extreme reduction of the external temperature.

- Other mechanisms able to potentially change the external pressure, such as tidal movement, shall be considered as well.

Design Case	Load Category	Environmental Condition	Pressure	Mooring Condition	FPU Heel Angle	Accidentally Flooded Compartments[1]	Free Hanging Flexible Jumper at URA
1	Operating	Max. Oper. (4, 5, 6)	Design	Intact	Zero	0	No
2	Extreme	Extreme (1, 2, 3, 7)	Design	Intact	Zero	0	No
3	Extreme	Max. Oper. (4, 5, 6)	Extreme	Intact	Zero	0	No
4a	Extreme	Max. Oper. (4, 5, 6)	Design	Damaged	Zero	0	No
4b	Extreme	Max. Oper. (4, 5, 6)	Design	Intact	Zero	1	No
5	Temporary	1-year	Associated	Intact	Zero	0	No
6	Test	Max. Oper. (4, 5, 6)	Hydrotest	Intact	Zero	0	No
8a	Survival	Extreme (1, 2, 3, 7)	Associated	Damaged	Zero	0	No
8b	Survival	Extreme (1, 2, 3, 7)	Associated	Intact	Zero	1	No
8c	Survival	Max. Oper. (4, 5, 6)	Design	Damaged	Zero	1	No
8d	Survival	Still Seawater	Design	Intact	Zero	2	No
8e	Survival	Extreme (1, 2, 3, 7)	N/A	N/A	N/A	0	Yes
8f	Survival	Max. Oper. (4, 5, 6)	Design	Intact	Nonzero[2]	0	No
9	Fatigue	Fatigue	Design	Intact	Zero	0	No

Table 4.3.3 – Design Case Load Matrix

Note 1 – Spare compartment shall be considered also flooded.

Note 2 – For all cases in Table 4.3.1 according to the considered FPU.

4. DESIGN REQUIREMENTS

4.1. GENERAL

Detailed Engineering Design of the FSHR system shall be performed in accordance with the minimum technical requirements specified in this section which shall be in line with the design principles.

The rigid jumper connected to the FSHR shall be designed considering all loads imposed by the FSHR, including survival, temporary and fatigue loads.

4.2. DESIGN LIFE

Design life will be informed by PETROBRAS for each particular case.

4.3. SOFTWARE AND MODELLING

Software packages used for the detailed engineering design of the FSHR system shall be capable of fulfilling the numerical modeling and analytical requirements in accordance with Section 3.2, and shall be supplemented, where appropriate, with the requirements outlined within this technical specification.

4.3.1. GLOBAL ANALYSIS SOFTWARE

Global static and dynamic analyses shall be performed using a three dimensional nonlinear finite element code suitable for the analysis of marine riser system: FLEXCOM or ORCAFLEX.

For FSHR design, fully non-linear time domain finite element analysis shall be performed.

The reference system for global analysis shall have axes parallel to the West-East and South-North directions.

4.3.2. LOCAL ANALYSIS SOFTWARE

Local analysis, where applicable, shall be performed using one of the following fully nonlinear FEA software: ABAQUS or ANSYS.

CONTRACTOR shall define software and element type able to consider any non-linear behavior of the model.

4.3.3. VIV ANALYSIS SOFTWARE

SHEAR7 shall be used for the VIV analysis.

4.3.4. FINITE ELEMENT MODEL CONSIDERATIONS

The FEM shall be a good representative of the FSHR system. The FEM of the FSHR shall be developed considering all key components and interfaces (e.g. BT, flexjoints, SJ, flexible jumpers, anti-corrosion coating, thermal insulation coating, VIV suppressors, etc.), including properties like weight, stiffness, hydrodynamic coefficients, etc.

FSHR global models shall incorporate a refined element mesh so as to sufficiently capture the riser response in areas of high curvature (if applicable), nonlinearities and dynamic response, typically at the flexible jumper/platform, top of riser and riser/seabed interface.

VIM and VIR over the BT shall be properly considered in the model.

FEM for the installation analyses shall be considered, incorporating at least the same level of detail of the in-situ model.

Components made of metal sheets should be preferred evaluated using shell elements; Components with complex geometry or variation on the wall thickness shall be analyzed using three-dimensional solid elements;

Note 1: Thin walled components shall present at least two solid elements through the wall thickness;

Note 2: Aspect ratio of the original elements shall be checked to avoid elements with high initial deformation. Initial mesh and aspect ratio evaluation shall be submitted to PETROBRAS approval;

Quadratic formulation elements are recommended to plate or solid elements.

4.4. FATIGUE SAFETY FACTORS

Typical minimum fatigue safety factors are presented in the table below:

LOAD CATEGORY	LOAD CASE	SAFETY FACTOR
In-place	First order	10
	Second order	
	Long term and storm VIV	20
	Long term and storm VIM	
	Long term and storm VIR	
Installation	Installation, VIV	10

Table 5.4.1 – Fatigue Safety Factors

Other reduced fatigue safety factors should be considered on case by case basis in accordance with standards and submitted to PETROBRAS approval. PETROBRAS will specify penalty factors to be multiplied by the specified in the tables in order to account the corrosion fatigue issues, according to the type of fluid and corrosive characteristics.

4.5. HYDRODYNAMIC COEFFICIENTS

CONTRACTOR shall document hydrodynamic coefficients used in the global analysis design. CONTRACTOR shall account for the following points with regard to hydrodynamic coefficients:

- Hydrodynamic flow regime (defined by Reynolds and Keulegan-Carpenter numbers);
- VIV occurrence and consequential drag amplification;
- Riser surface roughness including the effects of marine growth;
- Increase of drag loading due to the presences of VIV suppression devices (if applicable);
- Drag reduction to account for wake shielding of downstream risers in FSHR array. (Particularly for riser interference analysis);

CONTRACTOR shall base the design on conservative assumptions for hydrodynamic coefficients – i.e. higher drag coefficients where drag acts to excite the riser and lower drag coefficients where drag produces damping effects.

4.6. DESIGN DATA

CONTRACTOR shall propose on Design Basis any necessary consideration, based on the received input data, and submit for PETROBRAS approval.

Marine Growth shall be accounted for according to PETROBRAS environmental technical specifications.

5. DESIGN METHODOLOGY

The following paragraphs describe the minimum requirements that shall be considered in the detailed engineering design and global analysis of the FSHR.

5.1. WALL THICKNESS DESIGN

The wall thickness design shall be performed/confirmed according to the design code given in Section 3.2. The SJ shall be designed accordingly.

5.2. EXTREME RESPONSE ANALYSIS

5.2.1. EXTREME RESPONSE EVALUATION

CONTRACTOR shall set-up detailed finite element model of the FSHR system based on requirements described in Section 4.3.

Extreme response analysis shall be conducted as a minimum for the in-place FSHR system configuration and shall consider the following quasi static and dynamic loads: maximum vessel offset, extreme current loading and extreme wave events.

In cases when a FPSO is the chosen floating unit, all load cases shall be evaluated considering at least three different drafts of the FPU.

Dynamic riser response shall be based on time domain, irregular wave, random analysis, in order to capture the nonlinearities present in riser dynamic response, and shall consider wave loading and associated quasi static loads. A minimum time of 10800 sec. (3 hours) shall be evaluated. At least 500 harmonic components shall be used. Regular wave approach may be used restricted to the determination of the worst cases which shall be analyzed through the irregular wave approach.

5.2.2. Extreme Riser Response

The maximum interface loads and stress utilization factors shall be identified. Extreme riser responses to be determined during detailed design include:

- API (UC - Unity Check), DNV (CLCC - Combined Loading Criteria Check) and Tubular Joints Strength Check (to confirm integrity of riser line pipe);
- Interface loads used to design components, such as flexible riser jumpers, BT, SJ, flexible joint, tether bar, riser-pipeline jumpers, etc. (these loads include effective tension, shear force, bending moment, torque, displacement, rotation, etc.).

- Maximum flexible joint angle and maximum bending moment (to determine joints capacities);
- Assess the minimum radius, maximum depth and effective tension of the flexible jumpers during the dynamic analysis and verify compliance with the acceptance criteria.

5.2.3. Sensitivity Analysis

The robustness of the analysis shall be demonstrated through sensitivity studies of fundamental data parameters. The impact of the input data uncertainty over the results shall be evaluated.

Sensitivity studies shall be presented on the report, after results presentation.

At least the following uncertainty shall be evaluated:

- Hydrodynamic drag coefficient: a “riser VIV” drag coefficient amplification is applied on the taper joints and standard riser joint components and a “BT VIM” drag coefficient amplification is also applied on the BT;
- FSHR weight tolerances: the influence of the FSHR Condition Max Toler and Condition Min Toler on the riser response shall be analyzed ;
- URA installation tolerance: a misalignment angle of ±8 degrees between the FJ azimuth and the URA orientation has to be considered;
- Suction pile installation tolerance: the pile verticality is within ±3 degrees of vertical.
- Regular wave period: THmax can have a variation of ±15%;
- Irregular wave analysis: The irregular wave analysis (JONSWAP) is performed based on a 3hours time-domain analysis with the selected seed value.

5.3. FSHR FATIGUE RESPONSE ANALYSIS

The FSHR fatigue response shall be designed in accordance with Ref. [7] using S-N approach in association with the Palmgren-Miner rule, refer to [2] and [11];

The FSHR fatigue analysis shall consider the cumulative effects of all fatigue sources on the riser, including fatigue damage associated with:

a) In place fatigue damage due to:

- Direct wave loading;
- Wave frequency (first order) vessel induced motion;
- Low frequency (second order) vessel induced motion;
- Current induced VIV;

- Thermal effects;
- Vessel motion induced VIV;
- VIM and VIR over the BT;

b) Installation fatigue damage, during:

- Load-out;
- Tow-out;
- Deployment;
- Upending;
- Stand-by time (e.g., before FPSO hook-up).

Fatigue life shall be calculated in sixteen (16) points around each welded joint and parent material cross-sections chosen along the riser. Eight points around pipe internal wall and eight points around the external wall (see figure below).

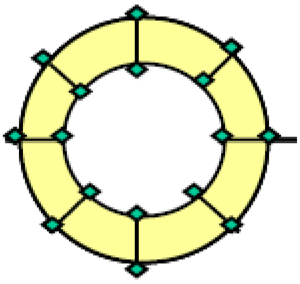

Figure 7.4.1 – Point around riser section for fatigue evaluation

SCF shall be considered and evaluated according to Ref. [7] for fatigue damage calculation of steel riser critical regions such as the riser girth welds, J-Lay collar, etc.

For the URA tubular connections SCF assessment, the Axial, In Plane Bending and Out of Plane Bending components shall be considered.

SCF shall be assessed by FEA models (recommendations given in Ref. [7]) and the results compared with:

- the modified Kellogg formulas and Marshall formulas (Ref. [14]);
- the Efthymiou formulas (Ref. [7]).

5.3.1. WAVE FATIGUE

Riser fatigue response to wave loading and wave induced first and second order vessel motions shall be evaluated using industry standard analysis;

Predicted fatigue life as a result of wave loading and first order vessel motions shall be combined with other fatigue sources, as described on Section 5.3.4, considering the safety factor defined on Section 4.4;

Wave fatigue analysis shall be evaluated based on a set containing between 1000 and 1500 sea states which will be properly supplied by PETROBRAS;

Time domain, irregular wave, random fatigue analysis approach shall be used;

Dynamic riser response may be based on random sea analysis and shall consider wave loading and associated quasi static loads. A minimum time of 10800 sec (3 hours) shall be evaluated. At least 500 harmonic components shall be used;

In order to identify the stress ranges and corresponding number of cycles contained in the predicted stresses time series, the Rainflow method shall be employed;

To reduce computational time, CONTRACTOR may propose a combination of time and frequency domain approaches in order to define a set of load cases to be analyzed in time-domain instead of the total cases. In this case, the main aspects are:

a) Fatigue damage due to all sea states shall be calculated in frequency domain;

b) Most damaging load cases shall be analyzed by irregular wave approach. Most damaging load cases shall be defined based on the following criteria:

- Load cases selected shall fulfill at least 90% of the total damage;
- At least 120 load cases shall be selected;

c) Damage calculated by time domain analysis shall be added to the damage evaluated by frequency domain for the other load cases, in order to define the total long term fatigue damage.

Extreme events (storm condition) also shall be considered to wave fatigue damage. The following extreme events shall be considered:

a) The most damaging sea state for 1-year return period with 3 hours duration, that is 0,03425% of occurrence;

b) The most damaging sea state for 10-year return period with a percentage of occurrence that corresponds to one occurrence of this storm for each 10 years of operational life;

c) The most damaging sea state for 100-year return period with a percentage of occurrence that corresponds to one occurrence of this storm for the entire life of the riser.

CONTRACTOR shall obtain the complete set of stress blocks used to the fatigue damage calculation in order to perform ECA evaluation.

The robustness of the analysis shall be demonstrated through sensitivity studies of fundamental data parameters. The impact of the input data uncertainty over the results shall be evaluated.

A sensitivity study shall be performed based on five (5) different random seed to select the one which provides the maximum bending moment and the maximum bending moment ranges within the elements of the URA and along the riser string (i.e. taper stress joints and standard riser joints) in the irregular wave time-domain analysis. CONTRACTOR shall submit for PETROBRAS approval the cases that will be assessed in the sensitivity study prior to beginning the analyses.

CONTRACTOR shall evaluate results and determine where further configuration optimization is possible and recommend for further work.

The deliverable, as defined in 7.6, shall be a report summarizing the wave fatigue response analysis procedure and results, including the fatigue damage of the FSHR system components due to waves and sensitivity results.

5.3.2. VIV FATIGUE

CONTRACTOR shall assess fatigue damage due to Vortex Induced Vibration – VIV over the riser.

The current profiles shall be considered as unidirectional along the riser length;

The riser modal response shall be evaluated using a global FEM program to generate mode shapes and modal curvatures. These responses are used as inputs to the VIV prediction software.

Riser VIV response shall account for current profile variations along the water column.

CONTRACTOR shall consider all current data including both short term extreme current data (Storm VIV) and long term current data. Short term or extreme current events duration is defined bellow:

- Two short term events shall be evaluated for each of the 16 directions for each extreme current profile.
- These events are called 10-year event and 100-year event.
- Each of these events are composed by a combination of 1-year, 10-year and 100-year currents;
- The 100-years event shall be assumed to occur once during the design life.

- The 10-years event shall be assumed to occur once for each 10 years of design life.
- Just the most damaging 10-year event and the most damaging 100-year event shall be considered to contribute in the total VIV damage;
- The combination of currents to the short term events is defined in table 7.4.1:

Phase	100-years Event		10-years Event	
	Return Period (years)	Duration (hours)	Return Period (years)	Duration (hours)
1	1	12	1	12
2	10	9	10	9
3	100	6	1	12
4	10	9	---	---
5	1	12	---	---
Total duration		48		33

Table 7.4.1 – Combination of currents to short term events

CONTRACTOR shall obtain the complete set of stress blocks used to the fatigue damage calculation in order to perform ECA evaluation.

The robustness of the analysis shall be demonstrated through sensitivity studies of fundamental data parameters. The impact of the input data uncertainty over the results shall be evaluated;

Sensitivity studies shall be presented on the report, after results presentation.

At least the following uncertainty shall be evaluated:

- Component weight tolerances;
- Addition of strakes (if applicable);
- Reduction in strake efficiency due to marine growth region (if applicable);
- Losses due to corrosion and variation in buoyancy.

CONTRACTOR shall evaluate results based on design criteria and, if necessary, consider improvements to mitigate VIV fatigue damage, e.g. increase of BT pulling tension, etc.

The deliverable, as defined in 7.8, shall be a report summarizing as a minimum the VIV, fatigue response analysis procedure, damage and sensitivity results, including recommendations for further optimization of the FSHR system.

5.3.3. VIM AND VIR FATIGUE

CONTRACTOR shall investigate the effects of Vortex Induced Motion – VIM and Vortex Induced Rotation - VIR over the BT on the fatigue damage of the whole system.

VIM and VIR shall be assessed by CFD models or by reduced scale testing, at CONTRACTOR discretion;

Special consideration shall be given to VIR during the period between installation of the vertical riser and installation of the flexible jumper. It shall be investigated if VIR in the BT could trigger a flow induced vibration called galloping in the structure due to URA geometry, before installation of the flexible jumper. On this phase, the flexible jumper may not be installed yet.

The current profiles shall be considered as unidirectional along the riser length.

VIM and VIR response shall account for current profile variations along the water column;

CONTRACTOR shall consider all current data including both short term extreme current data and long term current data. Short term or extreme current events duration will be defined bellow;

a) Two short term events shall be evaluated for each of the 16 directions. These events are called 10-year event and 100-year event. Each of these events is composed by a combination of 1-year, 10-year and 100-year currents;

b) Just the most damaging 10-year event and the most damaging 100-year event shall be considered to contribute in the total VIV damage;

c) The combination of currents to the short term events is defined on table 7.4.1. CONTRACTOR shall obtain the complete set of stress blocks used to the fatigue damage calculation in order to perform ECA evaluation.

The robustness of the analysis shall be demonstrated through sensitivity studies of fundamental data parameters. The impact of the input data uncertainty over the results shall be evaluated;

a) Sensitivity studies shall be presented on the report, after results presentation;

b) At least the following uncertainty shall be evaluated:

- Component weight tolerances;

CONTRACTOR shall evaluate results based on design criteria and, if necessary, consider improvements to mitigate VIM and VIR fatigue damage.

The deliverable, as defined in 5.3.3, shall be a report summarizing as a minimum the VIM and VIR fatigue response analysis procedure, damage and sensitivity results.

5.3.4. FATIGUE DAMAGE COMBINATION

The in-place fatigue damage along the riser length (first order, second order, VIV, VIM, and VIR due to short term and extreme currents contribution) shall be combined with the installation fatigue damage so that total fatigue damage fulfills the required design life. This will give the expected fatigue life of the riser system, define the compliance with the design criteria and demonstrate the need for design modifications;

The total system damage is defined by the following expression:

$$[(\text{Installation}) \times 10 + (\text{in-place 1st \& 2nd order}) \times 10 + (\text{in-place VIM \& VIV}) \times 20] \times AFF < 1.0$$

Where AFF (Additional Fatigue Factor) will be defined by PETROBRAS, when necessary;

The deliverable, as defined in 7.9, shall be a report summarizing the combined fatigue damage on the system during the design life and the fulfillment of the acceptance criteria.

5.4. IN-PLACE INTERFERENCE ANALYSIS

Interference analysis shall be performed according to [10] and manufacturer’s technical specifications.

CONTRACTOR shall design the FSHR system to avoid interference with adjacent structures (Including vessel hull, adjacent risers, umbilicals and mooring lines);

Interference analysis shall consider the same load case matrix used for extreme analysis, including accidental cases. Pre-selection of critical load cases may be performed based on quasi-static analysis.

The occurrence of Wake Induced Oscillations (WIO) shall be evaluated;

If wake effects are an issue for the FSHR system and the WIO are not accounted for in the analysis then a clearance limit of at least 5 pipe diameters shall be used to account for the uncertainty.

For interference analysis between flexible jumpers, critical load cases shall consider the combination of the strongest cross current with adjacent jumpers having a large difference in their weight/diameter ratios.

Clearances for each line shall be evaluated.

If clashing between flexible lines (flexible jumpers and umbilicals) were found, means to avoid it shall be investigated, such as: Increase or decrease the lengths of the jumper, Modification of jumpers' arrangement and height on the URA, use of bumpers, etc.

The robustness of the analysis shall be demonstrated through sensitivity studies of fundamental data parameters. The impact of the input data uncertainty over the results shall be evaluated.

5.4.1. Procedure for interference analysis

An FPSO drifting velocity of 2knots (1m/s) shall be assumed to verify the clearance between the FSHR and the adjacent catenary lines during their transient movements (e.g. broken mooring line).

The dynamic effects from wave loading shall be then assessed using regular wave time domain analysis. The clearances are then calculated at each time-step during the simulation.

The drag coefficients along the FSHR system shall be computed as a function of the Reynolds numbers.

Clashing or interference between the flexible jumper and any adjacent line is not allowed as well as between umbilicals.

A minimum clearance of 2 meters (edge to edge) is required between the FSHR system and any adjacent lines.

5.4.2. Multi-steps Analysis

For each clashing load case, the following steps are subsequently applied to calculate the minimum clearance during both:

(a) a quasi-static analysis (current and FPU offset due to one failed mooring line);

(b) a dynamic analysis (regular wave)

- Apply pretension for the mooring line
- Apply current profiles
- Apply FPU offset due to intact mooring lines (very slow drift motion)
- Apply additional FPU offset due to one failed mooring line (FPSO drifting velocity of 2knots (1m/s) is assumed)
- Apply regular wave using a Stokes 5th order wave

5.4.3. Sensitivity Analysis

The following sensitivity analyses shall be performed for the most critical load cases (min. clearance):

- Components weight tolerances
- Drag coefficient (VIV drag enhancement): the riser normal drag amplification factor due to riser VIV shall be directly output from the VIV analysis program and the BT normal drag amplification factor due BT VIM shall be used
- FPU incidental inclination shall be considered to verify the clearance between the flexible jumper and the platform hull.

The deliverable, as defined in 7.10, shall be a report summarizing as a minimum the in-place interference analysis procedure, interference and sensitivity results.

5.5. INSTALLATION ASSESSMENT

5.5.1. INSTALLATION PROCEDURE

The J-lay method may be used for the rigid section of the riser without restriction.

The Reel-Lay method may be used for pipes with OD ≤ 16in only.

The S-Lay method may be used provided that:

- A technical evaluation of the feasibility of performing all necessary connections using the S-Lay method.
- A risk assessment of the impact of the stinger in the FPU risers in a case of position loss.

Towing may be used if the following conditions are met:

- The Proponent presents the emitted installation environmental license and the deadlines for emission of operating license are compatible with project deadlines.
- A fatigue analysis must be performed proving that the towing operation is feasible considering the distance between construction site and installation site.

It shall be considered that both, the flexible jumper and the monitoring umbilical can be installed with a minimum significant wave height of 2.5m, regardless of the peak period considered.

For the conditions described above, the mandrels of the diverless connections shall be designed in a way that the connection of the lines can be done without the assistance of a tug boat. Therefore, the distance “d” between the longitudinal axis of the vertical riser and the connection point shall be dimensioned accordingly.

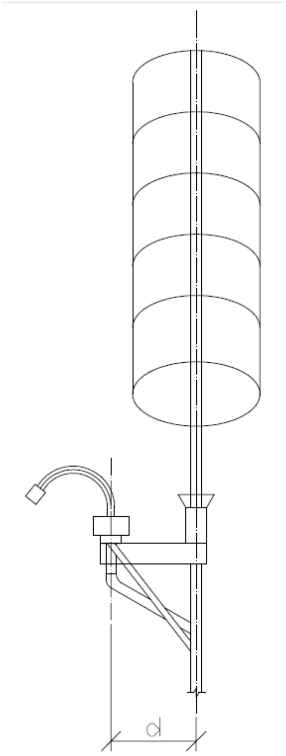

Figure 5.5.1 – Vertical access to the connection point of the flexible jumper and monitoring umbilical

5.5.2. INSTALLATION ANALYSIS

Regarding the installation of the rigid section of the FSHR the requirements of [35] shall be considered.

The BT installation analysis shall be performed according to Ref. [24]. At least the following steps during installation shall be investigated:

- Load-out;
- Towing;
- Ballasting / Upending;
- Lowering;
- Docking at FSHR URA.

5.5.3. INSTALLATION FATIGUE

CONTRACTOR shall perform a fatigue installation analysis to define the cumulated damage over the riser, based on Metocean data for installation analysis, provided by PETROBRAS.

CONTRACTOR shall evaluate the fatigue damage due to each phase described on installation procedure.

CONTRACTOR shall obtain the complete set of stress blocks used to the fatigue damage calculation in order to perform ECA evaluation.

The deliverable, as defined in 7.12, shall be a report summarizing as a minimum the installation fatigue analysis procedure and damage results, including recommendations for further optimization of the FSHR installation procedure.

6. COMPONENT DESIGN

6.1. GENERAL

CONTRACTOR shall provide technical specification for the components and accessories of the FSHR system, maximum loads and histograms of interface loads of the components;

The design of each FSHR component shall be based on applicable design codes and associated design criteria as identified by the component suppliers.

6.2. BUOYANCY TANK

BT shall be designed in accordance with the codes listed in Section 3.2.

BT shall be designed such that all length of the set BT + URA is contained within a WD between 100m and 250m.

BT shall be designed considering the possibility of its replacement in case of damage.

BT shall have a sufficient number of individual compartments, separated by internal bulkheads, to ensure an appropriate level of redundancy and buoyancy safety margin:

- The BT shall have a flooded spare compartment which will be drained in case of damage of another compartment.
- The riser shall be capable of normal operation with one compartment accidentally flooded (considering the spare compartment also flooded);
- The riser shall be capable of standing vertically or near vertically with two compartments accidentally flooded and survive an environment corresponding to an extreme event (considering the spare compartment also flooded);
- Any individual compartment may be accidentally flooded. The internal bulkheads design shall consider buckling loads for such situation (hydrostatic pressure effects resultant of a flooded compartment near a pressurized one).

BT shall have suitably located installation aids (e.g., padeyes, trunnions, and towing frames).

BT design shall consider pad-eyes that allow the installation of additional buoyancy devices in case of loss of compartments. Each pad-eye shall be able to sustain at least the buoyancy of two completely empty compartments. The pad-eyes fatigue life shall be compatible with the project life. The location of the pad-eyes shall be unobstructed and with ROV easy access.

The BT shall also be designed considering material and component weight tolerances.

The BT shall be designed to accommodate the following loads:

- Normal operating external loads;
- Installation loads;
- Potential internal load variations due to fabrication tolerances;
- Flooding of compartments for ballasting (or due to accidental damage) and de-ballasting.
- Internal fluid temperature fluctuations, seawater temperature fluctuations and tide fluctuations.

BT shell and internal bulkheads shall be designed considering maximum differential pressure possible for each part of structure corresponding to normal, extreme, installation conditions and accidental/survival conditions for the following scenarios:

- Hydrostatic pressure test (considered an extreme condition);
- Towing;
- Upending;
- In-place.

The BT compartments shall be designed to withstand, at least, internal and external differential overpressure of 2 bar. The concept of BT compartments open to ambient pressure of sea water (near pressure balanced) is not allowed. The BT shall be pressurized in operation and shall not be open to the sea.

6.2.1. Ballast system

Each compartment shall contain a nitrogen piping with a dedicated blocking valve and a water piping also with a dedicated blocking valve. The design shall consider that at least two valves must be open in order to allow the entrance or escape of fluid.

The valves materials shall be specified such that:

a) The expected corrosion allowance is compatible with the piping design.

b) The corrosion products shall not present potential damage to the valves.

The materials compatibility between valves, piping and BT shall be verified in order to avoid electrochemical corrosion.

The valves and piping system shall be located on the side opposite to the FPU and shall be protected against possible ROV collision.

All valves shall be ROV friendly.

6.2.2. ROV operations and divers auxiliary resources

Divers interventions shall be considered in the design as a contingency measure. Therefore, the following shall be considered:

a) Pad-eyes and anchoring structures to aid the loads motions next to critical components.

b) Stairs and platforms to give access to critical components.

6.3. RISER RIGID SECTION

The rigid section shall be designed considering the empty condition in any moment during the project life.

Regarding the safety class factor of Ref. [2], it shall be considered the safety class “HIGH” during operation.

The corrosion allowance shall be considered (when applicable) uniform along the perimeter and length of the riser.

6.4. ROTOLATCH CONNECTION

The connections between the URA and BT and between LRA and foundation shall consider rotolatches. Chains and SJ are not allowed.

CONTRACTOR shall specify the minimum requirements for the flexjoint interface in order to ensure and assure the reliability of the component.

Elastomeric material specification shall consider long-term mean external temperature and pressure;

Flexible joint shall be able to transfer all tensile, compressive and shear loads:

- Torsion motions of Buoyancy Tank shall be considered, especially for extreme failure cases;
- Transverse excitation modes (out of plane deflections) of flexible joint shall be considered (as potentially governing for flexible joint design).

Rotolatch shall also be designed considering material and component weight tolerances;

Flexible joint characteristics shall be considered in the global analysis of FSHR:

- Stiffness data used in the global analysis of FSHR shall be representative of the range of deflection predicted for each load case;
- Variation in stiffness with respect to amplitude and rate of rotation of flexible joint shall be considered.

6.4.1. FAT

At least the following tests shall be performed in order to verify the combination of axial loads, shear loads and rotations:

- Maximum design load and corresponding angle;
- Rotational stiffness measure for small and high angles up to the greatest allowable angle of the rotolatch.

Note: The measurement of the static rotational stiffness shall be performed in at least two orthogonal planes for the first rotolatch of each model in the project and in one plane for the other rotolatches of the same model.

At least, the following tests shall be performed as part of the FAT of the final product:

- Inspection of all rotolatches, including welding and non-destructive tests inspection;
- Complete visual inspection, including the external surface of the laminated component;
- Dimensional Inspection;
- Fit-up tests considering at least 3 attempts of coupling and decoupling for each evaluated coupling angle. At least two coupling angles shall be evaluated: zero degrees and the maximum expected angle during installation (but no less than 10 degrees). Also, the locking mechanism against accidental decoupling shall be tested.

6.4.2. Additional resources

A secondary locking system shall be provided in order to avoid the accidental decoupling of the rotolatches, mainly in cases of loss of tension. The system activation shall be ROV-friendly.

6.4.3. System redundancy

The design shall consider a solution in case of imminent fail of the rotolatch. The solution shall consider:

- The installation by ROV;
- A list of all necessary materials to provide the contingency, considering the compatibility with ROV;

- The assurance of fatigue resistance of the FSHR as well as external loads in the implementation of the solution.

6.5. TETHER BAR

CONTRACTOR shall specify the minimum requirements for the tether bar interface between BT and Rotolatch in order to ensure and assure the reliability of the component during the design service life.

Tether bar shall be able to transfer all tensile, compressive and shear loads:

- Torsion motions of Buoyancy Tank shall be considered, especially for extreme failure cases.

CONTRACTOR shall perform local analysis considering a detailed model of the tether bar and loads obtained on global analysis.

- If tether bar presents variation on the wall thickness (similar to a SJ), local analysis shall be performed considering three-dimensional solid elements.

6.6. UPPER RISER ASSEMBLY (URA)

Piping Spool standards shall be submitted for PETROBRAS approval.

If the flexible jumper is required to be pre-installed to the FSHR system prior to the arrival of the FPU in the field, the design of the URA assembly shall consider the associated loading due to installation and stand-by.

Piping and gooseneck shall comply with minimum curvature radius for pigging operations as required by PETROBRAS.

URA shall also be designed considering material and component weight tolerances.

The URA shall contain a pre-commissioning valve of type ball valve.

The deliverable shall include the design procedure, summarizing results and technical specification for URA, gooseneck and components.

6.7. LOWER RISER ASSEMBLY (LRA)

Bottom design comprises all items (LRA, bottom connection, risers/pipeline jumpers, etc.) in the zone from the foundation up to the main cross section of the FSHR bundle which starts at a certain distance above the seabed.

Piping and vertical connection hub shall comply with minimum curvature radius for pigging operations as required by PETROBRAS.

The LRA shall contain a pre-commissioning valve of type ball valve.

LRA shall also be designed considering material and component weight tolerances.

6.8. FOUNDATION

The foundation shall be composed by a suction pile. The suction pile shall contain at its top:

- A support for rotolatch coupling;
- A sheaves system to assist the coupling between the rotolatch at the LRA and the suction pile;
- The anodes of the cathodic protection system of the suction pile;
- Necessary vents for the installation of the suction pile;
- Bull’s eye for verification of verticality;
- A ROV panel.

The suction pile shall contain makings in order to monitor its installation depth.

The suction pile shall consider a verticality installation tolerance of ± 3 degrees.

Foundation design shall take into account:

- All positional installation tolerance inaccuracy (offset), orientation (twist) and verticality (tilt) requirements;
- Installation loads;
- Dynamic loads during life of field;
- De-commissioning loads;
- The foundation shall be designed to withstand installation and operational loads, without considering the gravity systems.
- On top of that, gravity systems to withstand at least 50% maximum overpull (50% effective tension on riser base) shall be designed and installed;

Foundation capacity is critically dependent on soil conditions. Geophysical and geotechnical data provided by PETROBRAS shall be considered in the foundation design.

Foundation corrosion protection shall be designed to have a cathodic protection system. The interaction with other cathodic protection systems shall be evaluated as part of the overall cathodic protection strategy.

6.9. STRESS JOINTS

If required, the SJs shall be designed and their characteristics incorporated to the FEM global model.

CONTRACTOR shall consider in the FSHR global analyses the SJs, including in the finite element model detailed geometry and material properties.

Contractor shall perform local analysis considering a detailed model of the SJ and loads obtained on global analysis; Local analysis shall be performed considering three-dimensional solid elements.

The deliverable shall include the design procedure, summarizing results and SJ technical specification.

6.10. CONNECTORS AND MCVS

The MCV dimensions shall not exceed the following envelope: Width: 4m, Length: 5m and Height: 11m.

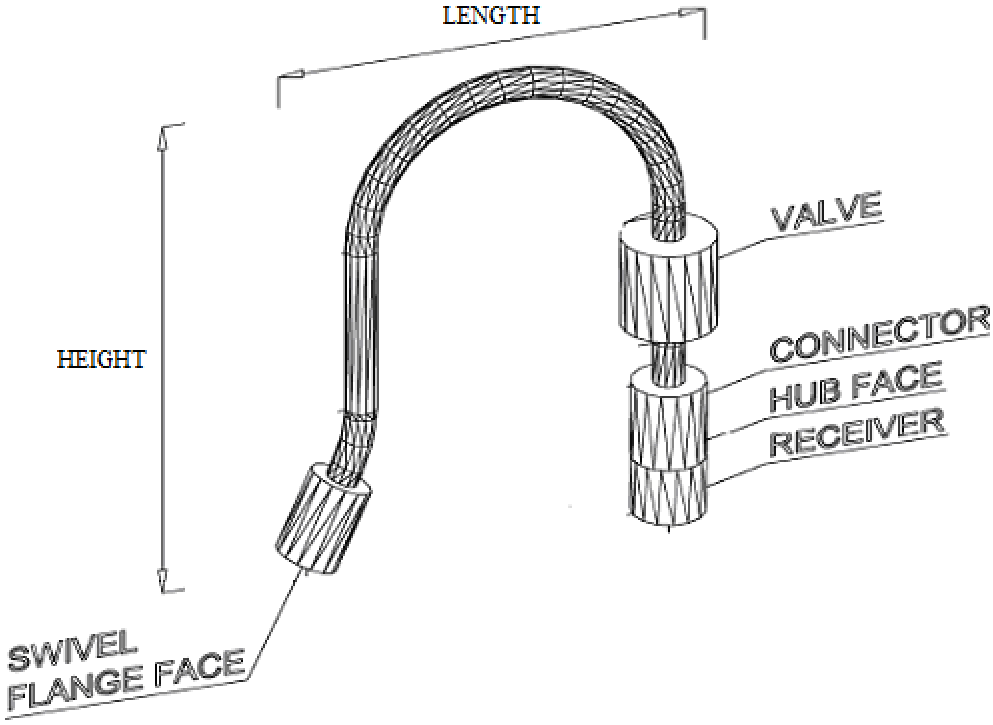

Figure 8.10.1 – MCV Schematic Drawing

A design basis for the MCV installation shall be submitted to PETROBRAS for approval prior to design load analysis execution.

Each MCV shall possess a pre-commissioning valve ROV-friendly.

The design loads shall consider at least the following load cases:

- Operation;
- Hydrotest;
- First or Second extremity connection on the FSHR.

A design premises report shall be submitted to PETROBRAS approval prior to the design analysis execution. This report shall contain, at least:

- All input data considered in the analysis;
- All load cases considered in the analysis.

The design premises shall be elaborated according to the requirements in Ref. [31].

6.11. MONITORING SYSTEM

The Monitoring System shall be in compliance with Ref. [26], [27] and [28].

The monitoring umbilical shall provide the electric power and communication (electric or optic) to the FSHR subsea monitoring system.

The following requirements shall be met:

- A minimum external diameter of 105mm shall be adopted;
- The minimum flooded weight in sea water shall be 20 kgf/m;
- All functionalities shall be redundant.

The support system of the monitoring umbilical shall be approved by PETROBRAS prior to support system design. The system shall be:

- Based in field proven systems;
- Designed in order to allow the pull-in/pull-out operation in the FSHR with the PETROBRAS available naval resources.
- Designed not to damage the umbilical.

The remote connection system shall be approved by PETROBRAS prior to design. Solutions based on the use of SUTs and flying leads are accepted but the detailed solution still shall be submitted to PETROBRAS for approval.

6.11.1. Training

A course shall be provided in order to train the monitoring system operators. The course shall be at least one week long.

7. DELIVERABLES

7.1. GENERAL

CONTRACTOR shall issue a number of design reports related with all activities described in this specification, following a scheduled in agreement with PETROBRAS representatives, before the commencement of the activities specified herein.

7.2. ORGANIZATION OF THE DOCUMENTS

All documents shall be supplied in electronic format (Word, Excel, MathCAD), and all drawings in Microstation V8. Original documents should also be supplied in .PDF format.

All text outside figures in the pdf format files shall be selectable in the Adobe Acrobat Reader, to allow copy and paste elsewhere for further utilization, if necessary.

All figures and drawings in the pdf files shall have good definition.

Before starting any design activity, CONTRACTOR shall submit for PETROBRAS any related data contained on this technical specification which requires previous PETROBRAS approval.

In order to keep the design robust and to avoid consistency problems, deliverables shall only present input information for the execution of the particular analysis.

7.3. DESIGN BASIS AND DESIGN PHILOSOPHY

The Design Basis shall contain all data provided by PETROBRAS, which are described in Section 4.6, and all additional information and data that will be used by CONTRACTOR during the detailed engineering design phase.

The Design Philosophy shall detail the criteria, safety factors and acceptance criteria from the pertinent codes and standards and describe the methodologies or procedures used in the FSHR design and all types of analyses of the FSHR.

The Design Basis and Design Philosophy shall include at least the following topics:

1 **Introduction**
    1.1 Detailed Design Objective
    1.2 Detailed Design Summary
    1.3 Conventions (Coordinates Systems, Unit System, wave and current conventions, etc)
    1.4 Software Packages
    1.5 Revision History
2 **Design Data**
3 **FSHR Design**
    3.1 General Features

- 3.2 Input data
- 3.3 Technical Requirements and Design Codes
- 3.4 Methodology

4 References

5 Appendix

- 5.1 Extreme Analysis Load case Matrix
- 5.2 Fatigue Analysis Load case Matrix
- 5.3 Converted RAO

7.4. WALL THICKNESS DESIGN REPORT

This report shall include objectives, related input data, detailed design procedures and methodologies, summarizing results, technical specifications and conclusions from wall thickness verification.

7.5. EXTREME ANALYSIS REPORT

This report shall include objectives, related input data, detailed design procedures and methodologies, summarizing results, technical specifications and conclusions from the Extreme response analysis.

The report shall contain as a minimum:

- The extreme response analysis procedure and design criteria;
- FSHR offsets and tilt;
- Flexible jumper tension versus angle plots, at FPU and FSHR sides;
- Flexible jumper minimum radius, maximum depth and maximum effective tension.
- Interface loads (at FPU and FSHR top and bottom);
- API (UC - Unity Check), DNV (CLCC - Combined Loading Criteria Check) and Tubular Joints Strength Check;
- Clear definition of critical load cases;
- Sensitivity results.

The input and output electronic files for worst cases shall be sent to PETROBRAS as well.

7.6. WAVE FATIGUE ANALYSIS REPORT

This report shall include objectives, related input data, detailed design procedures and methodologies, summarizing results, technical specifications and conclusions from the 1st and 2nd order wave fatigue analysis (see section 5.3.1).

7.7. VIV FATIGUE ANALYSIS REPORT

This report shall include objectives, related input data, detailed design procedures and methodologies, summarizing results, technical specifications and conclusions from the VIV fatigue analysis (see section 5.3.2).

7.8. VIM AND VIR FATIGUE ANALYSIS REPORT

This report shall include objectives, related input data, detailed design procedures and methodologies, summarizing results, technical specifications and conclusions from the VIM and VIR fatigue analysis (see section 5.3.3).

7.9. FATIGUE DAMAGE COMBINATION REPORT

This report shall summarize individual results and fatigue damage combination (see section 5.3.4).

7.10. IN-PLACE INTERFERENCE ANALYSIS REPORT

This report shall include objectives, related input data, detailed design procedures and methodologies, summarizing results, technical specifications and conclusions from the in-place interference analysis activity (see Section 5.4).

7.11. INSTALLATION ASSESSMENT REPORT

This report shall include objectives, related input data, detailed design procedures and methodologies, summarizing results, technical specifications and conclusions from the installation assessment activity.

7.12. INSTALLATION FATIGUE REPORT

This report shall include objectives, related input data, detailed design procedures and methodologies, summarizing results, technical specifications and conclusions from the VIM and VIR fatigue analysis (see section 5.5.3).

7.13. COMPONENT DESIGN REPORT

CONTRACTOR shall submit one individual report for each component design requested by PETROBRAS.

This report shall include objectives, related input data, detailed design procedures and methodologies, summarizing results, technical specifications and conclusions from the refereed component (see section 6).