PETROBRAS	TECHNICAL SPECIFICATION	Nº I-ET-3010.00-1519-274-PPC-001		
	CLIENT OR USER	E&P-SERV/US-IPSUB	SHEET 1 From 16	
	JOB OR PROJECT	PRODUCTION DEVELOPMENT	CC	
		UNITS AND PRODUCTION SYSTEMS		
CENPES	**RISER INTERFERENCE ANALYSIS**			

INDEX OF REVISIONS

REV.	*DESCRIPTION AND/OR AFFECTED SHEETS*
0	ORIGINAL

	ORIGINAL	REV. A	REV. B	REV. C	REV. D	REV. E	REV. F	REV. G
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1. PURPOSE

The riser system should be designed to avoid interferences. The design shall include evaluation or analysis of potential riser interference (including hydrodynamic interaction if relevant) with other risers and between risers and mooring lines, tendons, vessel hull, seabed, or any other obstruction [II]. Abnormal service conditions including the case of one mooring line damaged [II] and loss of buoyance module [V] shall be also considered. Interference should be considered during all phases of the riser design life, including installation, in-place and unusual events [II]. The accuracy and suitability of the selected analytical technique should be assessed when determining the probability and severity of contact.

This Technical Specification is applicable for Fixed or Floating Production Units (FPU) and has the purpose to provide minimum requirements for in-place interference analysis of risers with neighboring flexible risers, umbilicals, rigid risers (e.g. SCRs-Steel Catenary Risers and SLWRs-Steel Lazy Wave Risers), mooring lines, UNIT hull or structure or any other obstruction.

2. ABBREVIATIONS AND DEFINITIONS

- CONTRACTOR Company responsible for the interference analysis
- FPU Floating Production Unit (SS, FPSO in Turret or SM)
- shall Mandatory Requirement
- should Recommended Practice
- may On course of action
- Metocean Meteorologic & Oceanographic
- SS Semi-submersible
- SM Spread Mooring
- TDP Touch Down Point
- Hmax Maximum wave height
- THmax Period associated to Hmax
- RAO Response Amplitude Operator
- RHAS Hybrid Riser
- UNIT Fixed or Floating Platform
- MHR Multiple Hibrid Risers
- SLWR Steel Lazy Wave Riser
- SCR Steel Catenary Riser
- SSWR Steel Steep Wave Riser
- VIV Vortex Induced Vibration

3. APPLIED DOCUMENTS

[I]. I-ET-3010.00-1500-960-PPC-006 – Structural Analysis of Flexible Pipes, Rev. G

[II]. API RP 17B, Recommended Practice for Flexible Pipe, Fifth Edition,

[III]. DNV-RP-F203, Riser Interference, April 2009

[IV]. DNV-RP-C205, Environmental Conditions and Environmental Loads, August 2010

[V]. API RP 17L2, Recommended Practice for Flexible Pipe Ancillary Equipment

4. GENERAL REQUIREMENTS

Only time-domain analyses are allowed, since the linearization of the external loading as required by frequency-domain techniques is not applicable to hydrodynamic models incorporating interaction effects from adjacent risers.

Interference analysis shall be performed considering the transient (period from the application of loads to steady state is achieved) and the steady state conditions. Care shall be taken to evaluate the duration of the transient period for each application. In compliant configurations (such as lazy-wave) in deep waters, the time to achieve the steady state may be relatively long.

Wave data and Current profiles shall be obtained from the applicable Metocean Data (provided by PETROBRAS). If, for each direction, two types of current profiles (for instance, surface referenced velocities and mid-water referenced velocities) were provided, both shall be used for analysis. As required hereafter, an interference analysis shall be performed also by using currents normally adopted for fatigue evaluation, which shall be used to find the 98% Non-Exceedance current profile.

In case interference is identified, its progression shall be evaluated considering contact enabled between them (the interference may start in an allowed position of the riser, e.g. bare riser, and evolve to a position not allowed, e.g. intermediate connector or buoyance section); the sliding length and path shall be reported. The time step, riser segment discretization and pipe stiffness shall be adequately modelled to ensure correct model of the phenomenon. The progression of the contact point with the sliding of one riser over the other shall not, in any condition, extend to a region where interference is not allowed. It shall be documented by the CONTRACTOR that structural integrity will not be jeopardized and the fatigue life will not be affected and wear resistance shall be ensured. If deemed necessary by the CONTRACTOR, the contact energy, peak force and velocities at collision time and position may be also evaluated.

The premises for the interference analysis shall be submitted by the CONTRACTOR to PETROBRAS approval, presenting all the premises and methodology to be used. Alternative methodology, additional loading cases or any deviation from this specification shall be clearly explained by the CONTRACTOR on the premise for PETROBRAS evaluation and approval.

As the interference phenomena depends on the configuration of neighbors risers and is an interactive phenomenon, it is recommended that CONTRACTOR promotes design review meetings to update PETROBRAS about the evolution of the design and harmonize different risers' configurations from different CONTRACTORs. These meetings may occur between the Phases described in Table **2**.

4.1. Hydrodynamic Coefficients

The selection of hydrodynamic coefficients tends to introduce a source of uncertainty in the accuracy of the analysis results. In flexible pipe analyses, Cm is usually taken to be 2.0, while CD varies between 0.7 and 1.2. In most cases, it is normal practice to take 1.2 for extreme. However, other coefficients may be used if a justification is available (e.g. Re number dependency or real /small scale tests). It is always recommended to perform sensitivity studies to investigate the effect of the selected coefficients. Guidance on selection of drag coefficients for bare pipe, buoyancy modules and other accessories is given in DNV-RP-C205 [IV]. For straked sections, preferably values according to strake manufacturer laboratory tests shall be used. Care shall be taken to consider the actual Reynolds, Keulegan-Carpenter numbers and surface roughness due to marine growth.

VIV analysis shall be carried out to correct definition of hydrodynamic behavior and to account for a possible drag amplification factor. The geometry of the riser configuration, the hysteretic variation of stiffness and damping throughout the riser length (both, the viscoelastic and structural damping, considering the stick and slip behavior, shall be considered for flexible riser) shall be considered to correctly define drag coefficients amplifications for flexible risers and umbilicals.

The CONTRACTOR shall justify the adopted parameters such as stiffness and damping, the adequacy of chosen VIV software and the method and the parameters used to define the vibration modes. The drag amplifications due to VIV effect shall be considered with the correct variation with Reynolds Number and surface roughness. Care shall be taken to define the VIV analysis procedure in order to not over predict the drag amplification and any simplification like a 1.2 constant drag coefficient may be accepted if it is fully justified in the design premise. For justification on the methods, criteria, and parameters used in flexible pipe analysis, the CONTRACTOR may provide results gathered from field or lab monitoring of flexible risers.

As a conservative estimate, a value slightly on the upper bound side value for the drag amplification due to VIV is recommended for the upstream riser and on the lower bound value for the downstream. This will tend to bring the mean position of the risers closer to each other [III]. As there is very limited information regarding VIV behavior of a riser located in the wake of an upstream one, it is recommended to use no drag amplification on the downstream riser as a first estimation [III].

Thus, separate VIV assessments for the upstream and downstream risers are required prior to the global riser interference analysis and they should conservatively be treated as isolated risers [III] with no wake issues.

5. INTERFERENCE CRITERIA

The interference of risers with the following structures is not acceptable:

- Flexible or rigid risers in the buoyance sections (compliant configurations such as lazy-wave, pliant-wave or steep-wave);
- Mooring lines;
- Subsea arch and its tethers;
- UNIT hull or structures of Fixed Platforms;
- Straked sections;
- Unprotected accessories (such as unprotected intermediate end fitting of neighboring risers)

Depending on the environmental loading case (according to the table 1), the clashing between risers in the bare section (i.e. without any ancillary components) is allowed. Table **1** presents the acceptance criteria considering the riser interference and riser crossing below mooring lines.

Table 1 – Acceptance criteria for interference analysis

Environmental Loading Case (Current Return period)[2]	Interference Criteria
98% non-exceedance	No clashing[1] No umbilical riser crossing bellow any mooring line[1]
1-year	No flexible or rigid riser crossing below any mooring line[1]
100-year	Allowed interference between risers only in the bare section.

1: Unless otherwise specified by PETROBRAS.
2: Compass directions shall be considered for surface referenced currents and for Mid Water referenced currents

Interference is characterized by the contact of the upstream and downstream riser outer diameters (see Figure 1), considering coatings, floaters or any other appurtenances that may exist in the riser section.

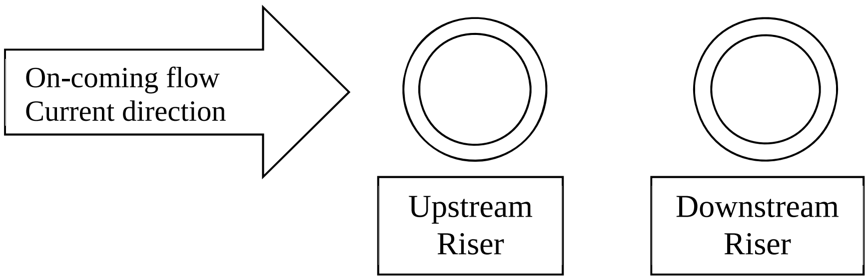

Figure 1 – Physical Risers Related Position

Unless otherwise specified by PETROBRAS, it’s not allowed for flexible or rigid risers to cross bellow mooring lines in annual conditions and umbilical risers in 98% non-exceedance conditions, due to the risk of a possible rupture of mooring line damaging the riser (or umbilical) during the fall.

The general environmental loading cases herein presented are intended to provide only the sea state conditions and combinations. The actual number of loading cases to be simulated will depend on the number of combinations of riser configurations and internal fluid densities.

6. LOADING CASES

The environmental loading cases for global analysis of riser interference combines the following parameters: FPU offset (magnitude and direction), current (profile, direction and return period) and waves (direction and return period).

Riser interference analysis shall be performed in phases as presented in Table **2**. Each phase will be used to select critical load conditions to perform the next one. If the riser configuration doesn't fulfill the acceptance criteria it shall be adjusted and the analysis restarted form phase 1.

Dynamic analysis may be performed only for the worst cases obtained from quasi-static analysis, with the critical combinations of vessel draft, vessel orientation, wave frequency, and wave heading that maximize riser motions and deflections, in the presence of currents.

All phases of interference analysis shall consider any possible variation of normal operation internal fluid density during the service life. Eventual operations conditions (temporary) using a non-operational fluid density and a special environmental window may be also requested by PETROBRAS considering the duration of the event and that the combined probability have to be lower than 10^{-4}.

Lower bound internal fluid weight (considering Start Of Life buoyance) shall be considered for upstream risers (to maximize risers' lateral displacement) while upper bound internal fluid weight (considering End Of Life buoyance and annulus flooded for flexibles risers) shall be considered for downstream risers (to minimize risers' lateral displacements), in order to achieve minimum clearances between each pairs. The opposite shall be also evaluated to check if the difference of configuration geometry could influence on the interference check.

For each riser, the interference analysis, could involve not only the two close by risers but risers that could be hanging on two or more slots apart. The range of risers involved in the analysis shall be fully justified.

Table 2 – Design Phases (for each combination of riser internal fluid density)

Load Case	Phase Description	Objective
Phase 1	Quasi-static Analysis without Offset	Choose worst currents
Phase 2	Quasi-static Analysis with Offset	Choose worst offset
Phase 3	Quasi-static Analysis with Offset and varying current direction	Sensitivity of current direction
Phase 4	Dynamic Analysis	Evaluate contact progression and riser drift due to dynamic movements
Phase 5	Damage conditions	Sensitivity of damaged conditions

6.1. Phase 1 – Quasi-static Analysis without offset

Load cases of Phase 1 are presented on Table **3** and Table **4**, the objective is to define critical current profiles and shall include all current profiles listed on Metocean Data Technical Specification with current direction referenced to the surface or for mid depth (e.g. level of 800 m), for:

- extreme current conditions (1 and 100 year conditions) and
- currents for fatigue analysis (to evaluate the 98% non-exceedance case).

Table 3 – Load Cases for Quasi-static Interference Analysis for riser x riser - without offset

Case	Current	Offset	Upstream Riser	Downstream Riser	Number of cases[1]
Surf 1.1	100 years	w/o offset	Lower Bound Weight	Upper Bound Weight	16
Surf 1.2	98% non exc.	w/o offset	Lower Bound Weight	Upper Bound Weight	16
Surf 1.3	100 years	w/o offset	Upper Bound Weight	Lower Bound Weight	16
Surf 1.4	98% non exc.	w/o offset	Upper Bound Weight	Lower Bound Weight	16
Mid 1.1	100 years	w/o offset	Lower Bound Weight	Upper Bound Weight	16
Mid 1.2	98% non exc.	w/o offset	Lower Bound Weight	Upper Bound Weight	16
Mid 1.3	100 years	w/o offset	Upper Bound Weight	Lower Bound Weight	16
Mid 1.4	98% non exc.	w/o offset	Upper Bound Weight	Lower Bound Weight	16
				Maximum number of cases	128

1 – Number of cases estimated considering 16 directions of current profiles

Table 4 – Load Cases for Quasi-static Interf. Analysis for riser x mooring line - without offset

Case	Current	Offset	Upstream Riser	Downstream	Number of cases[1]
Moor- Surf 1.1	100 years	w/o offset	Lower Bound Weight	Mooring line	16
Moor - Surf 1.2	1 year	w/o offset	Lower Bound Weight	Mooring line	16
Moor - Surf 1.3	98% non exc. (umb x moor.)	w/o offset	Lower Bound Weight	Mooring line	16
Moor - Mid 1.1	100 years	w/o offset	Lower Bound Weight	Mooring line	16
Moor - Mid 1.2	1 year	w/o offset	Lower Bound Weight	Mooring line	16
Moor - Mid 1.3	98% non exc. (umb x moor)	w/o offset	Lower Bound Weight	Mooring line	16
				Maximum number of cases	96

1 – Number of cases estimated considering 16 directions of current profiles

If any acceptance criteria is not fulfilled risers configuration shall be adjusted and phase 1 repeated prior to proceed to next phase.

All cases that interference between bare risers occurs shall be chosen to be deeper analyzed in the following phases. Besides that, at least three additional critical cases (e.g.: closest risers cases) among the cases performed shall be also chosen to proceed to the next phase. These $N_{dircrit}$ (NDIRCRIT number of bare risers interference cases plus critical cases) cases shall be analyzed in phase 2.

At least three critical cases, $N_{dircrit\_moor}$ (NDIRCRIT-MOOR, number of critical cases for interference between risers and mooring) among the interference check between risers and mooring lines cases (Table **4**) shall be chosen to perform the phase 2.

In this first phase CONTRACTOR may model all risers together to catch the overall behavior of the risers system, including relations of upper/lower weight that are critical, for the following phases.

6.2. Phase 2 – Quasi-static Analysis with offset

Once there is no correlation between current and wave, for each current direction chosen on previous phase ($N_{dircrit}$ plus $N_{dircrit\_moor}$ cases), any offset direction is possible, but not all relative direction between wave and current could cause the maximum offset, four offsets are defined for each set of current profiles (maximum at surface or maximum at mid water). The main goal of the 2nd phase is to define critical offset directions and load cases are presented on Table 5 for interference riser x riser and Table 6 for interference riser x mooring line. If any acceptance criteria is not fulfilled risers configuration shall be adjusted by the CONTRACTOR and the procedure shall be restarted from phase 1.

Table 5 – Load Cases for Quasi-static Analysis with offset – Interference Riser x Riser

Case	Current	Offset direction	Max offset	# of cases
Surf 2.1	100 years	Collinear	Maximum 100 years	$N_{dircrit}$
Surf 2.2	100 years	Non collinear up to +/- 45° apart	Maximum 100 years	4 * Ndircrit
Surf 2.3	100 years	Non collinear from +/- 67.5° up to +/- 135° apart	Half of Maximum 100 years	8 * $N_{dircrit}$
Surf 2.4	100 years	Non collinear more than +/- 157.5° apart	No offset	(already analysed on previous phase)[1]
Surf 2.5	98% non exc.	Collinear	Maximum 1 year	$N_{dircrit}$
Surf 2.6	98% non exc.	Non collinear up to +/- 45° apart	Maximum 1 year	4 * $N_{dircrit}$
Surf 2.7	98% non exc.	Non collinear from +/- 67.5° up to +/- 135° apart	Half of Maximum 1 year	8 * $N_{dircrit}$
Surf 2.8	98% non exc.	Non collinear more than +/- 157.5° apart	No offset	(already analysed on previous phase)[1]
Mid 2.1	100 years	Collinear	Half of Maximum 100 years	$N_{dircrit}$
Mid 2.2	100 years	Non collinear up to +/- 45° apart	Half of Maximum 100 years	4 * $N_{dircrit}$
Mid 2.3	100 years	Non collinear from +/- 67.5° up to +/- 135° apart	No offset	(already analysed on previous phase)[1]
Mid 2.4	100 years	Non collinear more than +/- 157.5° apart	Half of Maximum 100 years, opposite direction	3 * $N_{dircrit}$
Mid 2.5	98% non exc.	Collinear	Half of Maximum 1 year	$N_{dircrit}$
Mid 2.6	98% non exc.	Non collinear up to +/- 45° apart	Half of Maximum 1 year	4 * $N_{dircrit}$
Mid 2.7	98% non exc.	Non collinear from +/- 67.5° up to +/- 135° apart	No offset	(already analysed on previous phase)[1]
Mid 2.8	98% non exc.	Non collinear more or than +/- 157.5° apart	Half of Maximum 1 year, opposite direction	3 * $N_{dircrit}$
				42 * $N_{dircrit}$

Note 1: Some cases of relative direction of current and wave could end up with null offset (opposite direction of wave and current for the surface current and around 90º for mid water currents with maximum at 800 m), in these cases the worst case is already chosen in phase 1 and shall be further analyzed in next phases.

Table 6 – Load Cases for Quasi-static Analysis with offset – Interference Riser x Mooring

Case	Current	Offset direction	Max offset	# of cases
Moor - Surf 2.1	100 years	Collinear	Maximum 100 years	$N_{dircrit-Moor}$
Moor - Surf 2.2	100 years	Non collinear up to +/- 45° apart	Maximum 100 years	4 * $N_{dircrit-Moor}$
Moor - Surf 2.3	100 years	Non collinear from +/- 67.5° up to +/- 135° apart	Half of Maximum 100 years	8 * $N_{dircrit-moor}$
Moor - Surf 2.4	100 years	Non collinear more than +/- 157.5° apart	No offset	(already analysed on previous phase)[1]
Moor - Surf 2.5	1 year	Collinear	Maximum 1 year	$N_{dircrit-Moor}$
Moor - Surf 2.6	1 year	Non collinear up to +/- 45° apart	Maximum 1 year	4 * $N_{dircrit-Moor}$
Moor - Surf 2.7	1 year	Non collinear from +/- 67.5° up to +/- 135° apart	Half of Maximum 1 year	8 * $N_{dircrit-Moor}$
Moor - Surf 2.8	1 year	Non collinear more than +/- 157.5° apart	No offset	(already analysed on previous phase)[1]
Moor - Surf 2.9	98% non exc. (umb x moor.)	Collinear	Maximum 1 year	$N_{dircrit-Moor}$
Moor - Surf 2.10	98% non exc. (umb x moor.)	Non collinear up to +/- 45° apart	Maximum 1 year	4 * $N_{dircrit-Moor}$
Moor - Surf 2.11	98% non exc. (umb x moor.)	Non collinear from +/- 67.5° up to +/- 135° apart	Half of Maximum 1 year	8 * $N_{dircrit-Moor}$
Moor - Surf 2.12	98% non exc. (umb x moor.)	Non collinear more than +/- 157.5° apart	No offset	(already analysed on previous phase)[1]
Moor - Mid 2.1	100 years	Collinear	Half of Maximum 100 years	$N_{dircrit-Moor}$
Moor - Mid 2.2	100 years	Non collinear up to +/- 45° apart	Half of Maximum 100 years	4 * $N_{dircrit-Moor}$
Moor - Mid 2.3	100 years	Non collinear from +/- 67.5° up to +/- 135° apart	No offset	(already analysed on previous phase)[1]
Moor - Mid 2.4	100 years	Non collinear more than +/- 157.5° apart	Half of Maximum 100 years, opposite direction	3 * $N_{dircrit-Moor}$
Moor - Mid 2.5	1 year	Collinear	Half of Maximum 1 year	$N_{dircrit-Moor}$
Moor - Mid 2.6	1 year	Non collinear up to +/- 45° apart	Half of Maximum 1 year	4 * $N_{dircrit-Moor}$
Moor - Mid 2.7	1 year	Non collinear from +/- 67.5° up to +/- 135° apart	No offset	(already analysed on previous phase)[1]
Moor - Mid 2.8	1 year	Non collinear more than +/- 157.5° apart	Half of Maximum 1 year, opposite direction	3 * $N_{dircrit-Moor}$
Moor - Mid 2.9	98% non exc. (umb x moor.)	Collinear	Half of Maximum 1 year	$N_{dircrit-Moor}$
Moor - Mid 2.10	98% non exc. (umb x moor.)	Non collinear up to +/- 45° apart	Half of Maximum 1 year	4 * $N_{dircrit-Moor}$
Moor - Mid 2.11	98% non exc. (umb x moor.)	Non collinear from +/- 67.5° up to +/- 135° apart	No offset	(already analysed on previous phase)[1]
Moor - Mid 2.12	98% non exc. (umb x moor.)	Non collinear more or than +/- 157.5° apart	Half of Maximum 1 year, opposite direction	3 * $N_{dircrit-Moor}$
				42 * $N_{dircrit-Moor}$

Note 1: Some cases of relative direction of current and wave could end up with null offset (opposite direction of wave and current for the surface current and around 90º for mid water currents with maximum at 800 m), in these cases the worst case is already chosen in phase 1 and shall be further analyzed in next phases.

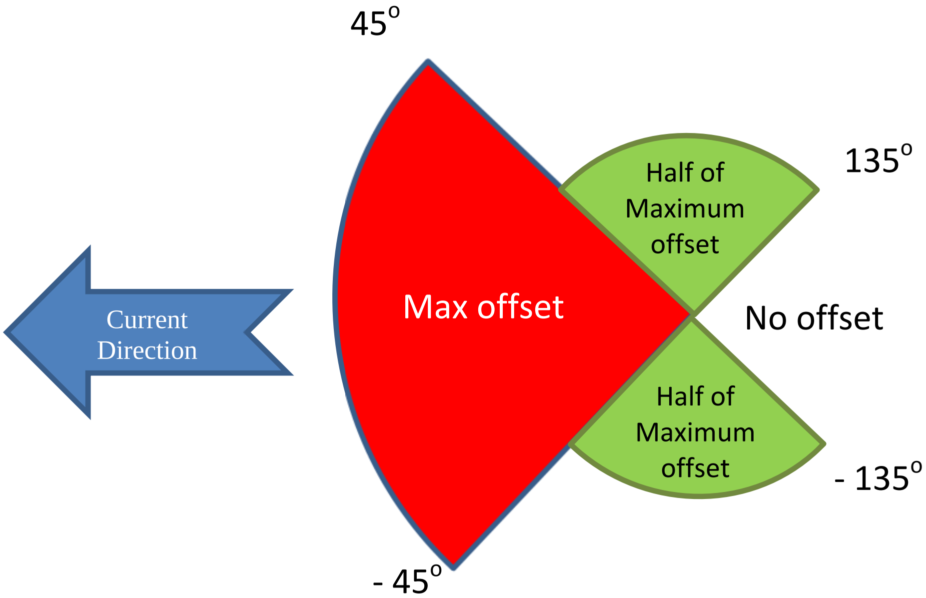

Figure 2 – Offset distribution for Surface Referenced Current cases

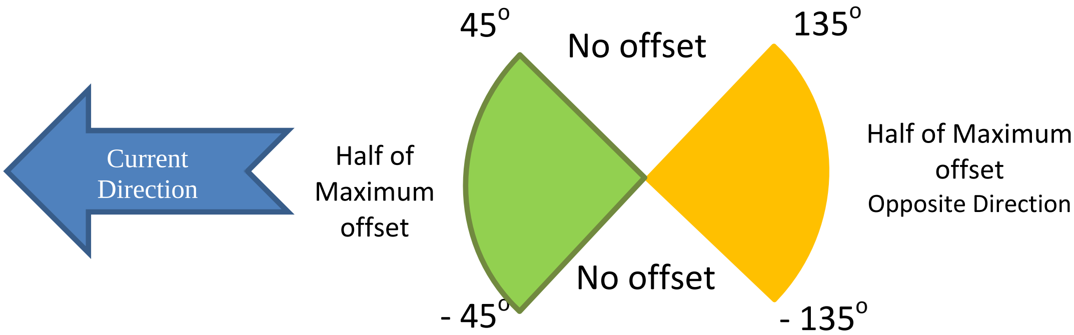

Figure 3 – Offset distribution for Mid Water Referenced Current cases

6.3. Phase 3 – Quasi-static Analysis with current rotation

Each current profile direction represents not only the Compass direction (e.g.: N, NNE, NE …) but a range of directions that could be 22,5º or 45º wide, depending on how refined the Metocean Data is presented. The main goal of the 3rd phase is to find the critical direction within the sector of the current direction chosen on phase 1. Load cases are presented on Table **7** for interference riser x riser and Table 8 for interference riser x mooring line.

If any acceptance criteria is not fulfilled risers configuration shall be adjusted by the CONTRACTOR and the procedure shall be restarted from phase 1.

Table 7 – Load Cases for Quasi-static Analysis with current direction rotation – Interference Riser x Riser

Case	Current	Offset	Number of cases
Surf 3.1	Worst Current profile of 100 years	Worst associated offset defined on phase 2	4
Surf 3.2	Worst Current profile of 98% of non-exceedance	Worst associated offset defined on phase 2	4
Mid 3.1	Worst Current profile of 100 years	Worst associated offset defined on phase 2	4
Mid 3.2	Worst Current profile of 98% of non-exceedance	Worst associated offset defined on phase 2	4
		Total Number of cases (based on sectors of 22,5º)	16

Table 8 – Load Cases for Quasi-static Analysis with current direction rotation – Interference Riser x Mooring line

Case	Current	Offset	Number of cases
Moor - Surf 3.1	Worst Current profile of 100 years	Worst associated offset defined on phase 2	4
Moor - Surf 3.2	Worst Current profile of 1 year	Worst associated offset defined on phase 2	4
Moor - Surf 3.3	Worst Current profile of 98% of non-exceedance (umb x moor.)	Worst associated offset defined on phase 2	4
Moor - Mid 3.1	Worst Current profile of 100 years	Worst associated offset defined on phase 2	4
Moor - Mid 3.2	Worst Current profile of 1 year	Worst associated offset defined on phase 2	4
Moor - Mid 3.3	Worst Current profile of 98% of non-exceedance (umb x moor.)	Worst associated offset defined on phase 2	4
		Total Number of cases (based on sectors of 22,5º)	16

For cases presented on Table **7** and Table **8**, entire current profiles shall be rotated from their original Compass direction ±7,5º and ±15º if sectors are defined each 22,5º degrees in Metocean Data or ±10, ±20 and ±30º if sectors are defined each 45º.

6.4. Phase 4 – Dynamic Analysis

Following Quasi-static phases Dynamic Analysis shall be performed to evaluate the wave contribution to the interference. The worst cases chosen among those analyzed in previous phases shall be dynamic analyzed considering waves with the same direction of the offset applied (if no specific directions are available). Load cases are presented on Table 9 for interference of riser x riser and Table 10 for interference riser x mooring line.

For each direction, the worst wave among the contour curve of extreme Hs x Tp presented in the Metocean data shall be considered (e.g. Spectrum which can cause the Maximum Heave Acceleration or other fully justified). Regular or irregular wave analyses methodologies are acceptable. In both cases, sufficient analysis time shall be simulated to confirm a stable position. It should be noted that a deterministic wave approach may incur in a long transient with unreal TDP displacement, been preferable an irregular wave approach.

Table 9 – Load Cases for Dynamic Analysis – Interference riser x riser

Case	Current	Offset	Wave	Number of cases
Surf 4.1	Worst Current profile of 100 years	Worst associated offset defined on phase 2	10 years	1
Surf 4.2	Worst Current profile of 98% of non-exceedance	Worst associated offset defined on phase 2	1 year	1
Mid 4.1	Worst Current profile of 100 years	Worst associated offset defined on phase 2	10 years	1
Mid 4.2	Worst Current profile of 98% of non-exceedance	Worst associated offset defined on phase 2	1 year	1
			Total Number of cases	4

Table 10 – Load Cases for Dynamic Analysis – Interference riser x mooring line

Case	Current	Offset	Wave	Number of cases
Moor - Surf 4.1	Worst Current profile of 100 years	Worst associated offset defined on phase 2	10 years	1
Moor - Surf 4.2	Worst Current profile of 1 year	Worst associated offset defined on phase 2	1 year	1
Moor - Surf 4.3	Worst Current profile of 98% of non-exceedance (umb x moor.)	Worst associated offset defined on phase 2	1 year	1
Moor - Mid 4.1	Worst Current profile of 100 years	Worst associated offset defined on phase 2	10 years	1
Moor - Mid 4.2	Worst Current profile of 1 year	Worst associated offset defined on phase 2	1 year	1
Moor - Mid 4.3	Worst Current profile of 98% of non-exceedance (umb x moor.)	Worst associated offset defined on phase 2	1 year	1
			Total Number of cases	4

If any acceptance criteria is not fulfilled risers configuration shall be adjusted by the CONTRACTOR and the procedure shall be restarted from phase 1.

As stated before, in case interference between risers is identified, its progression shall be evaluated considering contact enabled between them. The time step, riser segment discretization and pipe stiffness shall be adequately modelled to ensure correctly modelling of the phenomenon. The progression of the contact with the sliding of one riser over the other shall not, in any condition, extend to a region where interference is not allowed.

6.5. Phase 5 – Sensitivity Analysis

The sensitivity loading cases matrix for interference analysis between risers in Table 11 and between risers and mooring lines are presented in Table 12. The critical loading cases selected and analyzed on phase 4 shall be considered for this phase.

Two sensitivity studies shall be performed, one for offset with one mooring line damaged and the other to account for the loss of buoyance modules as per [V] (applicable to risers with configurations with attached flotation or weight modules, e.g. lazy-wave, steep-wave, pliant-wave, etc.) or one compartment flooding of buoyance tanks in subsea arch (applicable to risers with configurations like: lazy-s, RHAS, MHR, etc.).

Table 11 – Sensitivity (Dynamic) environmental loading cases matrix

Case	Current	Offset	Wave		Number of cases
Surf 5.1	Worst Current profile of 100 years	Damaged offset in the worst direction defined on phase 2	10 years		1
Surf 5.2	Worst Current profile of 98% of non-exceed.	Damaged offset in the worst direction defined on phase 2	1 year		1
Surf 5.3	Worst Current profile of 100 years	Intact offset in the worst direction defined on phase 2	10 year	Loss of buoyance modules or compartment flooding	1
Surf 5.4	Worst Current profile of 98% of non-exceedance	Intact offset in the worst direction defined on phase 2	10 years	Loss of buoyance modules or compartment flooding	1
Mid 5.1	Worst Current profile of 100 years	Damaged offset in the worst direction defined on phase 2	10 year		1
Mid 5.2	Worst Current profile of 98% of non-exceedance	Damaged offset in the worst direction defined on phase 2	1 year		1
Mid 5.3	Worst Current profile of 100 years	Intact offset in the worst direction defined on phase 2	10 year	Loss of buoyance modules or compartment flooding	1
Mid 5.4	Worst Current profile of 98% of non-exceedance	Intact offset in the worst direction defined on phase 2	1 year	Loss of buoyance modules or compartment flooding	1
				Total Number of cases	8

Table 12 – Sensitivity (Dynamic) environmental loading cases matrix

Case	Current	Offset	Wave		Number of cases
Moor - Surf 5.1	Worst Current profile of 100 years	Damaged offset in the worst direction defined on phase 2	10 years		1
Moor - Surf 5.2	Worst Current profile of 1 year	Damaged offset in the worst direction defined on phase 2	1 year		1
Moor - Surf 5.3	Worst Current profile of 98% of non-exceedance (umb x moor.)	Damaged offset in the worst direction defined on phase 2	1 year		1
Moor - Surf 5.4	Worst Current profile of 100 years	Intact offset in the worst direction defined on phase 2	10 year	Loss of buoyance modules or compartment flooding on midwater buoy	1
Moor - Surf 5.5	Worst Current profile of 1 year	Intact offset in the worst direction defined on phase 2	1 yeas	Loss of buoyance modules or compartment flooding on midwater buoy	1
Moor - Surf 5.6	Worst Current profile of 98% of non-exceedance (umb x moor.)	Intact offset in the worst direction defined on phase 2	1 yeas	Loss of buoyance modules or compartment flooding on midwater buoy	1
Moor - Mid 5.1	Worst Current profile of 100 years	Damaged offset in the worst direction defined on phase 2	10 year		1
Moor - Mid 5.2	Worst Current profile of 1 year	Damaged offset in the worst direction defined on phase 2	1 year		1
Moor - Mid 5.3	Worst Current profile of 98% of non-exceedance (umb x moor.)	Damaged offset in the worst direction defined on phase 2	1 year		1
Moor - Mid 5.4	Worst Current profile of 100 years	Intact offset in the worst direction defined on phase 2	10 year	Loss of buoyance modules or compartment flooding on midwater buoy	1
Moor - Mid 5.5	Worst Current profile of 1 year	Intact offset in the worst direction defined on phase 2	1 year	Loss of buoyance modules or compartment flooding on midwater buoy	1
Moor - Mid 5.6	Worst Current profile of 98% of non-exceedance (umb x moor.)	Intact offset in the worst direction defined on phase 2	1 year	Loss of buoyance modules or compartment flooding on midwater buoy	1
				Total Number of cases	8

7. INTERFERENCE ANALYSIS RESULTS AND CONCLUSIONS

As a minimum, the following analysis outputs shall be provided for the critical loading cases:

- Table presenting the minimum clearance between risers and neighboring structures (others risers, mooring lines, RHAS/MHR, etc.) along the riser length occurring during each phase (for quasi-static and dynamic simulations);
- For each phase shall be presented a result summary showing worst cases and the justification for the chosen cases to be analyzed in following phases;
- For each pair analyzed, graphic of the critical cases with clearance between risers and neighboring structures (others risers, mooring lines, RHAS/MHR,etc.), along the riser length, from top view;
- For each riser, pictures showing the most critical interference (if any), in 3D model view and decomposed view (top view, lateral view and front view);
- For compliant configurations such as lazy-wave, pliant-wave and lazy-s, the maximum horizontal displacement of the sag bend and of the hog bend regions for each riser function shall be presented;
- Results of 100-year and 1-year environmental conditions shall be presented separately, considering both criteria (interference and crossing below mooring lines);
- Conclusions and recommendations of the interference analysis shall be included in a separate chapter (beginning of the interference report);
- Clashing energy, force or velocity (what CONTRACTOR considers necessary) of the critical loading cases selected to perform the damage evaluation and comparison with the allowed damage capacity.

It shall be presented a critical analysis of the results, with main conclusions and technical recommendations.