Interference Assessment Between Top Tensioned Risers Using a Comprehensive Screening Approach

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ABSTRACT

Interference between top tensioned risers (TTRs) is a key design challenge. Due to TTR tensioner stroke limits combined with large vessel offsets, the space out of wellheads is limited. Therefore, riser-to-riser contact is more likely to occur in extreme current conditions.

Riser clearance between adjacent risers is evaluated accounting for the effects of wake, vortex-induced vibrations, current directionality (including variation through-depth), vessel offset, riser configuration, and drilling sequence. Accounting for all of these effects simultaneously and in detail when assessing TTR interference can be challenging.

The typical TTR array interference approach consists of a combination of riser deflection shape matching and detailed wake assessment. In this paper, a revised TTR interference analysis approach is discussed, with the inclusion of an intermediate step involving screening for critical riser pairs using a simplified wake model assessment. Riser deflection shape matching ensures that the likelihood of clashing is minimized. The riser interference screening process avoids detailed wake modelling of non-critical riser pairs. The screening analysis method emphasizes avoidance of false positives (unrealistic riser clashing pairs) and false negatives (missing riser clashing pairs). It employs a simplified conservative wake model using a stratified downstream current profile to determine which riser pairs are critical and warrant detailed wake modelling. To illustrate the efficiency of the screening approach, results from this approach are compared to results from analysis with detailed wake modelling.

An implementation of this approach is presented for riser joints with fairings and strakes. Nominal drag coefficients for these joints are obtained based on experimental testing and/or computational fluid dynamics simulations. Drag amplification of the upstream riser is obtained from vortex induced vibration (VIV) analysis and is also incorporated in the analysis.

INTRODUCTION

Interference analysis is conducted to evaluate the risk of riser clashing and is critical to the design of risers, especially in deep and ultra-deep water applications. DNV RP F203, [6], and API RP 2RD, [4], procedures can be applied for riser interference assessment. The global riser analysis described in these procedures for a single pair of risers includes current loads and a hydrodynamic interaction model. The general philosophy is that riser collision is not allowed under normal, extreme or survival conditions, [4] [6] [10]. These procedures can be extended to an entire array of risers.
The typical riser interference assessment for an array of risers is conducted using the two-step approach illustrated in Figure 1. In Step 1, riser deflection profiles are matched to select suitable parameters that can maximize riser clearance. This step is used to minimize the likelihood of riser clashing during detailed wake interference assessment. In Step 2, a detailed wake interference assessment is carried out. However, interference analysis can be carried out only two risers at a time (pair-wise) because of restrictions in wake modelling.

Depending on the project, some of the parameters can be moved from fixed to controllable and vice versa. If there are a large number of riser pairs that will need to be assessed, this requires a higher number of controllable parameters (high flexibility) to mitigate the risk of riser clashing. This paradigm is illustrated in Figure 3.

Typically, the number of riser pairs in an array of risers at risk of clashing is manageable because of similarities in riser from slot-to-slot, sheared current profiles and riser top tension factors. However, in an array of dissimilar risers with varying configurations and complex current profiles, the number of critical riser pairs increases significantly. Additionally, there can be in-slot drilling risers where an individual well is drilled from its designated wellbay slot. Also, there can be across-slot drilling risers where wells are drilled from a designated drill center not from the associated wellbay slot.

**PROBLEM DEFINITION AND METHODOLOGY**

In an array of 15 production risers with 15 in-slot and across-slot drilling risers and considering directional current profiles, there may be as many as 2,500 riser pairs that need to be assessed. The most comprehensive strategy for riser interference analysis is to model all risers in an array and include wake effects for all adjacent riser pairs. Because of the large number of possible pairs, performing detailed wake analysis for an array of multiple in-slot and across-slot risers can often be rendered infeasible under reasonable project deadlines and schedules.

In such a situation, a heuristic tool that can efficiently screen and make decisions is needed. This requires a change in approach from the typical two-step riser interference analysis approach illustrated in Figure 1 to the three-step riser interference analysis approach illustrated in Figure 4. This alternate approach includes an intermediate step involving the use of a simplified wake model that can efficiently minimize and quantify the risk of clashing. The proposed three-step approach is as follows:

Step 1. **Riser Parametric Definition** (top tension, VIV suppression and riser configuration selection) in which analysis is conducted with an extreme (100 year)

![Figure 1 – Typical Riser Array Interference Analysis Approach](image)

The occurrence of clashing between risers can be attributed to the following factors, [6] [7] [10]:

- Initial riser separation due to wellhead spacing at seafloor and vessel wellbay spacing;
- Well drilling sequence;
- Magnitude and direction of environmental loads;
- Riser effective tension distribution (submerged weight, internal fluids and top tension);
- Vessel offset due to environmental loading and accidental loading such as mooring line failure;
- Cross sectional area increase due to VIV suppression devices;
- Hydrodynamic phenomena such as current shielding and/or galloping due to wake induced oscillations and drag amplification due to VIV (accounting for the presence of suppression, if applicable).

Ultimately, clashing is largely due to relative differences in properties of adjacent structures. These properties can be classified as fixed (cannot be changed) and controllable (can be altered) parameters, as detailed in Figure 2.

![Figure 2 – Wake Interference Assessment Parameters](image)

<table>
<thead>
<tr>
<th>Fixed Parameter</th>
<th>Controllable Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel Payload</td>
<td>Well Drilling Sequence</td>
</tr>
<tr>
<td>Riser Configuration</td>
<td>VIV Suppression</td>
</tr>
<tr>
<td>Current Loads</td>
<td>Riser Top Tension</td>
</tr>
<tr>
<td>Vessel Offsets</td>
<td></td>
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<tr>
<td>Wellbay Layout</td>
<td></td>
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<tr>
<td>Slot Assignment</td>
<td></td>
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<tr>
<td>Seabed Layout</td>
<td></td>
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<tr>
<td>TTR Stroke</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 3 – Controllable Parameters and Flexibility](image)

![Figure 4](image)
current profile and nominal riser tensioner loads are adjusted for each riser type to maximize clearance.

Step 2. **Riser Operation Parameter Definition** to screen and select critical adjacent riser pairs in the matrix of TTRs using a simplified wake model while accounting for the well drill sequence.

Step 3. **Detailed Wake Interference Analysis** to identify regions of potential clashing while accounting for wake effects for critical pairs.

To get an idea of the scale of each step, Step 1 could involve 2 different risers (production riser, drilling riser), Step 2 could involve 2,500 pairs (15 risers in array, 10 directions, and 2 riser types) and Step 3 could involve a reduced set of approximately 20-50 pairs. Further refinement of Step 2 can result in significant reduction in the number of pairs and directional sectors analyzed in Step 3.

This paper focuses on the proposed riser interference approach with particular emphasis on Steps 1 and 2 to define operational parameters and minimize riser interference. It is assumed that an array of TTRs is deployed from a floating vessel and is subjected to current loads with a simplified wake model. It is important to note that the selection of critical riser pairs using the simplified wake model is not trivial. The approach used must be robust to changes in parameters while having high accuracy such that riser pairs are not missed (avoiding false negatives). The conservatism must be sufficient but not excessive.

**LITERATURE REVIEW**

Riser clashing due to current and wave loads and the consequent WIO shielding has been investigated by Huse, [1], Huse and Kleiven, [9] and Duggal and Niedzwecki, [12] [13]. Huse and Kleiven, [9], suggest that the risk of riser clashing can be mitigated by ensuring equal payout, i.e., the risers have similar deflection profiles when subjected to current loads. Also, fendering elements can be used to mitigate the effects of riser collision. Also, as discussed in Huse and Kleiven, [9], if risers are straked, collisions are likely to be inelastic with both

Koska et al., [5], assessed riser interference due to current and wave loading in an array of 15 TTRs deployed from a TLP. In this work, riser clashing risk was minimized by using strakes along the length of the riser, optimizing the drilling riser top tension through riser deflection profile matching with adjacent production risers.

**INTERFERENCE ASSESSMENT THEORY**

A simplified riser schematic of the upstream-downstream riser pair and the associated current profile is illustrated in profile view in Figure 5 and plan view in Figure 6. The drag and lift coefficients are defined in terms of functions of non-dimensional distances, L/Du and T/Du, where L and T denote the in-line and transverse distances between the centerlines of the downstream and upstream cylinders, and Du is the drag diameter of the upstream cylinder.

When the downstream cylinder is within the wake generated by the upstream cylinder, it experiences a reduced drag force due to reduced mean current velocities in the wake and a lift force across the cylinder.

**Figure 4 – Proposed Riser Array Interference Analysis Approach**

- **Figure 5 – Upstream-Downstream Riser Pair with Current**
- **Figure 6 – Cylinder Model Plan View with Current**
The riser interference acceptance criteria are to be in accordance with the choice of one of two codes: DNV, [6], and API, [4]. Per the DNV code, interference assessment considering wake is not expected and further analysis is not necessary if the minimum edge to edge spacing exceeds the sum of the structural (shell) diameters as shown in Figure 7. This criterion is based on the assumption that no VIV drag amplification is included.

Figure 7 – Minimum Spacing Criterion

Per the API code, the acceptance criteria are based on the requirement that under survival current loads, the edge to edge distance does not result in ancillary (fin to fin) or structural (shell to shell) contact, as shown in Figure 8 for a fairing-strake pair. Examples of riser ancillary component and structural component clashing in riser models are shown in Figure 9 and Figure 10, respectively.

Figure 8 – Ancillary and Structural Clashing Criterion

Figure 9 – Example of Riser Ancillary Component Clashing
(Stakes and Fairings not Shown)

Figure 10 – Example of Riser Structural Clashing

TOOLS

Analysis of each riser pair is performed using global 3-D finite element models with the most onerous environmental loads and conducted in FLEXCOM software, [3]. This analysis considers the following:

- Current loading from 100 year return period surface and bottom currents;
- Upstream riser VIV drag amplification, [10], with drag amplification for unsuppressed sections obtained from a riser model implemented in VIVA (commercial VIV software);
- Downstream riser drag reduction using the wake field theory of Huse, [1], and Blevins, [2], for circular cylinders

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and CFD/experimental coefficients as described in Patel et al, [11], for pairs of cylinders with strakes and/or fairings.

The analysis considers the potential for interference between the following riser pairs:
- Two adjacent production risers
- Drilling riser and an adjacent production riser.

TOP TENSIONED RISER DESCRIPTION

The production riser is a dry tree system and the drilling riser is a high pressure system with a surface BOP. For the production riser, VIV suppression strakes are present on the majority of the riser length. Most of the drilling riser length has fairings with the buoyancy joint having staggered fairing sections (alternate joints faired). The remaining length of the drilling riser is either fitted with VIV suppression strakes (near the base of the riser) or is bare (in the splash zone).

A listing of the riser OD, nominal drag and added mass coefficients for the production and drilling riser joints and ancillary components is given in Table 1. The configurations of the production and drilling risers are shown in Figure 11.

<table>
<thead>
<tr>
<th>Table 1 – Riser Drag Coefficients</th>
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<tbody>
<tr>
<td>Riser Structural Component</td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Fairied Buoyant Joint (8 Fairings/ Joint)</td>
</tr>
<tr>
<td>Staggered Fairied Buoyant Joint (8 Fairings/ Joint)</td>
</tr>
<tr>
<td>Bare Buoyant</td>
</tr>
<tr>
<td>Fairied Slick Joint (8 Fairings/ Joint)</td>
</tr>
<tr>
<td>Drilling Riser Straked Pipe (^{3})</td>
</tr>
<tr>
<td>Production Riser Straked Pipe (^{4})</td>
</tr>
<tr>
<td>Bare Pipe</td>
</tr>
</tbody>
</table>

\(^{1}\) Corresponds to OD of other riser components that do not have strakes/fairings.

\(^{2}\) With VIV drag amplification, from VIVA software analysis.

\(^{3}\) Drilling riser steel OD is 21.25 inch and strake shell thickness is 0.25 inch.

\(^{4}\) Production riser steel OD is 14.50 inch and strake shell thickness is 0.25 inch.

The drag and lift coefficients vary as a function of distance along the lateral axis from the center of the upstream riser and are obtained from Huse, [1], Blevins, [2], or from Patel et al, [11]. The approach of using lift and drag coefficients is valid for cylinder-to-cylinder distances of greater than 2-3 times the diameter of the upstream cylinder. At distances less than this value, the interaction becomes more complex with suction forces (negative drag forces) coming into play.

RISER ARRAY

An example of an array of vertical or near vertical TTRs operating from a floating vessel is illustrated in Figure 12 where 15 production risers occupy various slots and drilling risers take the place of these production risers during various stages of the project life cycle.

In the riser layout shown in Figure 12, the minimum initial center-to-center spacing between adjacent wellbay slots is 20ft and the minimum initial nominal spacing between adjacent wellheads is 28ft. The narrow spacing, vessel payload limitations, pre-determined drilling sequence, complex current loads and the different types of risers make the management of interference between these risers challenging.
CURRENT LOADING

Depending on the field metocean conditions, the currents used can be quite onerous, with extreme (100-year return period) surface currents as high as 4 knots and bottom currents of the order of 2 knots. Furthermore, these bottom currents are often independent of the surface currents. Example current profiles are shown in Figure 13.

For all load conditions, both magnitude and direction of the current profile is specified through the water column. As the current profiles vary significantly with direction, this directionality must be accounted for while screening for critical risers. Some fields exhibit current data such that omnidirectional data can be assumed and thus the screening process would no longer have this variable.

STEP 1: RISER PARAMETRIC DEFINITION

Riser parameters including top tension, riser configuration and VIV suppression device placement are defined based on extreme current loading, no vessel offset and with the riser initial position vertically above the wellhead. This approach also accounts for riser payload limitations, different VIV suppression devices and variations in hydrodynamic coefficients for upstream and downstream conditions. Riser parametric definition allows for quick definition of optimal tensions early in the project cycle, thus decoupling critical design activities (pipe sizing, tensioner design, deck space-out, etc.) and analysis activities (strength, fatigue) while the interference analysis progresses in parallel.

**Initial Riser Deflection Shape Matching**

An example illustration of riser deflection shape matching between two in-slot production risers and two in-slot drilling risers when subjected to 100 year return period currents are shown in Figure 14 and Figure 15, respectively.

**Deflection Shape Matching of Dissimilar Risers**

The deflection shapes of tandem production and drilling risers when subjected to 100 year return period currents is shown in Figure 16. However, this result indicates clashing of the upstream production riser with the downstream drilling riser. This occurs in the region indicated by the rectangular box. This clashing occurs because of the high drag loading from production riser straked joints and low drag loading from drilling riser faired joints.
To increase the separation between the two risers, two solutions are feasible:

- Riser active tension management by changing top tensions for the risers depending on different current environments, both current speed and direction;
- Riser configuration adjustment by changing the location, extent and coverage of buoyancy joints in drilling riser and/or VIV suppression devices in production and/or drilling risers. The presence/absence of VIV suppression devices results in different deflections because of the differences in drag coefficients for bare pipe, straked pipe and faired pipe as given in Table 1.

**Riser Design Changes to Minimize Clashing**

In the example considered, active tension management was not considered feasible because of the preference for a passive system, especially because this is an integrity and reliability issue during an unmanned scenario. Additionally, the maximum allowable riser top tension is constrained by the allowable vessel payload (fixed constraint). Consequently riser configuration adjustment where an initially fully faired drilling riser is replaced with 800ft of strakes is considered.

As shown in Figure 17, this change ensures that the deflection profiles of the production and drilling risers are as identical as feasible and that there is sufficient clearance between upstream/downstream production and drilling risers. The large diameter of the buoyancy modules, combined with the presence of strakes on the rest of the riser can lead to high drag loading on the riser while the presence of fairings can lead to low drag loading on the riser. The introduction of strakes results in increased drag forces and higher deflections in the slick joint region when the drilling riser is subjected to bottom currents. As a consequence, the risk of riser clashing is reduced. This approach is also used to determine the location and extent of buoyant joints and staggered fairings.

**Directional Current Response in TTR Array**

After the riser parametric definition is completed, current loads in multiple directions is used to characterize the riser array response. An example of the response to current loading with no offset and with no wake effects for an array of risers is shown in Figure 18.

Each sub-figure in Figure 18 is subjected to current loading towards that direction. For example, the top left template within Figure 18 is subjected to current loading towards the northerwestern direction. The purpose of this illustration is to show how closely packed TTR arrays are and the extent of riser deflection when subjected to high current loads.

**STEP 2: RISER OPERATION PARAMETER DEFINITION**

At the end of Step 1, the riser configuration, top tension, tension distribution, and VIV suppression device extent and
locations have been determined. At this point in the project, it is typically difficult to make substantial changes to these parameters. The risk of riser clashing is then controlled by making operational changes, whether through top tension control or through drilling sequence and drill center changes.

**Simplified Wake Model**

Riser operation parameters are defined by performing riser screening using a simplified wake model; *i.e.*, by incorporating downstream riser drag reduction. Reduced current loading results in a reduction in the drag force, and in effect replicates the effects of wake shielding. This is carried out all throughout the water column for the downstream riser while maintaining full current loading on the upstream riser. This screening process avoids detailed wake modelling of non-critical riser pairs by employing a simplified, conservative wake model. Thereby, riser pairs that are critical and warrant detailed wake modelling can be identified. This conservative, yet realistic approach also mitigates the risk of identifying too many pairs by considering the downstream riser immovable or too few pairs by disregarding wake effects. Also, VIV of the downstream risers is neglected, to be conservative for interference analysis.

To ensure sufficient conservatisms, the minimum drag ratio (average drag coefficient at closest approach without suction forces to nominal drag coefficient) from test data is applied. This is justified because the deflection profiles of the upstream and downstream risers have been matched in Step 1 and the wellbay slot separation distance is at least 2-3 times the structural diameter of the upstream component. Based on Patel et al. [11], the measured minimum reduction in the drag ratio for risers with strakes or fairings is approximately 0.25. Note that a drag ratio of 0.25 translates to an equivalent current ratio of 0.5 based on the relationship between current, drag ratio and drag force,

\[
F_D = \frac{1}{2} C_{d0} \lambda_d \rho U_0^2 D_u
\]

(1)

where, \(C_{d0}\) denotes the undisturbed drag coefficient for the downstream cylinder, \(\lambda_d\) is the coefficient factor (drag ratio) calculated based on wake effects, \(F_D\) is the drag force per unit length, \(U_0\) is the undisturbed current speed, \(D_u\) is the upstream drag diameter and \(\rho\) is the fluid density.

The use of a uniform drag ratio along the entire riser can lead to an unrealistically large number of pairs given the narrow wellbay spacing. A preferable approach is to use a zone-wise stratification approach to scale the downstream current profiles. This zone-wise stratification results in a simplified wake model as shown in Figure 19. This illustration shows two lines:

1) Constant drag ratio (ratio of shielded drag to nominal drag) of 0.25; and,

2) Stratified drag ratio with values varying along the water column. The strata and their corresponding drag ratios are determined by quantifying the closest approach for the riser array with the downstream riser being subjected to a drag ratio of 0.25 for multiple pairs and with multiple current profiles.

![Figure 19 – Simplified Wake Models for Downstream Riser](image)

Specifically, three zones of the simplified wake model, characterized by varying relative levels of clashing likelihood, are identified based on conservative drag ratios:

- **Zone 1**: Maximum separation distance (near the top and the bottom of the riser);
- **Zone 2**: Moderate separation distance, due to shielding effects in this zone and to allow for a smooth transition in drag and current profiles between maximum and minimum separation zones;
- **Zone 3**: Minimum separation distance or high clashing likelihood zone.

The width of Zone 3 in the above figure can be used to limit the number of pairs assessed. In this instance, because of bottom currents, a wider Zone 3 region was chosen. Note that it is not necessary to limit the simplified wake model to 3 zones. In other words, the zones (width, number) can be optimized depending on the clashing problem.

Clearance between riser pairs is assessed between upstream risers subjected to 100% of the current and downstream risers subjected to shielded currents defined using the zone-based simplified wake model approach.

**In-Slot Production Riser Pairs**

The number of critical riser pairs in an array of 15 production risers is obtained using full current for the upstream riser and simplified wake models consisting of both constant drag ratio and stratified drag ratios. The results of the assessment are shown in Figure 20. A reduction in the number
of critical pairs obtained is evident through the bar chart comparing the total number of riser pairs and that of the critical riser pairs obtained from the simplified wake models. To highlight the number of critical riser pairs, the results for the diameter sum clearance criterion is shown in Figure 21.

![Figure 20](image)

**Figure 20 – Production Riser/Production Riser Pairs using a Simplified Wake Model**

![Figure 21](image)

**Figure 21 – Production Riser/Production Riser Pairs using a Simplified Wake Model (Diameter Sum Clearance Criteria)**

Based on the results obtained, it can be ascertained that:

- Screening with full current on the downstream riser is potentially under-conservative;
- A significant reduction in the number of pairs can be obtained by using a simplified wake model for the in-slot production riser pairs and the effect is evident for all 3 clashing criteria (structural, ancillary, and diameter sum);
- Screening with a uniform drag ratio of 0.25 on the downstream riser is potentially over-conservative and can result in the identification of an unnecessarily large number of pairs;
- This methodology of screening with a simplified wake model using a zone-based stratification of downstream current can result in a reduced number of identified pairs and is a more realistic, yet still conservative approach.

**Drilling Sequence**

Based on the array of 15 in-slot production risers, the maximum number of possible riser pairs is 105 per loading direction. However, this pertains only to the number of in-slot risers with similar configuration. If 15 in-slot and across-slot drilling risers are also included, 152 additional pairs per direction will need to be assessed.

This number can be further reduced if the well drilling sequence is considered. For instance, the C1 drilling riser shown in Figure 22 is used to drill through wellhead C2. The neighboring production risers are D1, D2, B1 and B2. If wellhead slot C2 is drilled before slot D1 and B2, the total number of pairs that will need to be assessed reduces to 4 (2 drilling riser upstream – production riser downstream pairs and 2 production riser upstream – drilling riser downstream pairs) based on adjacent production riser in slots B1 and B2.

This approach can be extended for all the drilling risers in the TTR array and the maximum number of riser pairs that will need to be assessed is reduced to more manageable numbers (75-100). However, even with this reduced number, generating 180-200 sets of FEA models (accounting for the in-slot production riser pairs) to perform the necessary analysis can prove to be cumbersome. A preferred approach to identify the number of riser pairs that may clash is through an automated screening process where each riser is subjected to current loads separately, and then assessing riser clearance pair-wise.

![Figure 22](image)

**Figure 22 – C1 Drilling Riser to Wellhead C2 and Adjacent Production Risers**

**Drilling Riser/Production Riser Pairs**

An array of 15 production risers is considered with a drilling riser replacing production risers occupying both the associated wellbay slot and wellhead depending on whether we have in-slot or across-slot drilling. The number of critical riser pairs obtained using full current for the upstream and downstream risers and simplified wake models consisting of a reduction in current profile based on both 50% of full current and stratified current profiles are shown in Figure 23.
Based on the results obtained, it is observed that the trends are similar to those observed for the in-slot production riser/production riser pairs with the following differences:

- The number of riser pairs is significantly more than that obtained for the in-slot production riser pairs because of dissimilar risers and across-slot drilling.
- The reduction in number of riser pairs due to the use of the zone-base stratification is not as pronounced as in the in-slot production riser pairs and is primarily attributed to the presence of the across-slot drilling risers.

From the results of the stratified current profile, 19, 27 and 102 production riser/production riser and production riser/drilling riser pairs out of a total of 2,101 possible pairs (1,155 production riser/production riser and 946 production riser/drilling riser pairs) are identified through the structural, ancillary and sum of diameter separation clashing criterion, respectively. The large number of riser pairs identified can be attributed to the presence of buoyant joint fairings, which may occupy significant cross-sectional area in relation to the wellbay slot size.

The riser pairs obtained are consistent with the expectation that the drilling riser upstream with a production riser downstream exhibits the more onerous interference loading condition. One reason for this expectation is that the drilling riser contains fairings and they are assumed to align their fins along the current direction towards the downstream riser.

These pairs can then be subjected to either detailed wake assessment or further fine tuning based on the outlined screening approach to identify the sector of current headings which are critical for riser interference.

**STEP 3: DETAILED WAKE INTERFERENCE ASSESSMENT**

Detailed wake interference is then conducted with one of the critical riser pairs identified by the screening study. This pair is assessed with detailed wake coefficients based on Huse’s model, Blevins’ model or user-defined coefficients, [11] and is implemented in Flexcom. The minimum clearance results as a function of current direction for one pair (upstream: drilling riser from wellbay slot C4 to drill well slot D3 and downstream: production riser in slot C3) is also considered. Additionally, offset conditions are considered and the most conservative results are shown in Figure 24.

This minimum clashing distance occurs at a water depth of 1,200 ft below the mean water level. The results obtained indicate that there is a sector of current bearings of 15 degrees over which there is ancillary clashing for the riser pair. This result is consistent with the relative magnitudes of clashing results obtained from the screening study, where the edge-to-edge clearance between the two risers (with no vessel offset) was such that the downstream riser crosses over by as much as 20ft. This result indicates that the screening study identifies a riser pair with potential risk of clashing. However, detailed wake assessment suggests that the potential risk of ancillary clashing is low, accounting for the probability of occurrence of the 100 year return period current that occurs within a specified current bearing sector 15 degrees wide. This result also shows that the simplified wake model is conservative.

**SCREENING METHODOLOGY BENEFITS**

Apart from efficient screening of riser pairs, this approach can also be used to identify the preferred drilling sequence, drill center(s) and wellbay positioning relative to well center. This approach can also be used to identify the benefits of VIV suppression devices (such as fairings and low drag strakes) by quantifying the likelihood of riser interference all throughout the riser array.

This approach is particularly beneficial from a project efficiency and delivery perspective because optimization and/or feasibility assessments can be conducted quickly. For instance, during the project phase, the drilling sequence can be varied and analysis results can be post-processed with minimum
additional computational effort to identify the preferred drilling sequence. Also, riser top tensions are selected early in a project life cycle and hence riser design is largely de-coupled from detailed interference assessment. The analysis is made more efficient and detailed analysis can be delayed until greater maturity is achieved, thereby reducing significant rework and saving time.

CONCLUSIONS

Riser interference assessment represents a key design challenge for top tensioned risers because of the proximity between risers, limited vessel payload, limited riser splay and stroke, and dissimilar riser configurations. It is important to address riser interference early in the design phase while it is still possible to make changes in riser configuration, tension, wellbay and wellhead locations, and tensioner stroke.

A revised methodology for riser interference assessment is presented with addition of a step involving riser screening using a simplified wake interference model. The use of a simplified wake model based on current speed reduction to account for riser shielding and suction effects on the downstream riser provides a robust, modular approach. This approach can also be automated to perform screening analysis for interference assessment of a large array of risers.

A heuristic screening tool that lends itself to automation and efficiently screen for critical riser pairs has been developed. This tool provides flexibility to the riser analyst and project engineer by enabling operational changes that can limit/eliminate the risk of riser clashing. One key benefit is that this approach can be undertaken early in the project with limited information and allows scope for refinement as more information becomes available without accumulating significant computational burden from detailed wake assessment.

NOMENCLATURE

DR Drilling Riser
PR Production Riser
TTR Top Tensioned Riser
VIV Vortex Induced Vibration

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REFERENCES