Feasibility of Steel Lazy Wave Risers in the North Sea

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Agenda

• Risers in deepwater North Sea
• Are steel catenary risers (SCR) suitable?
• Case for steel lazy wave risers (SLWR)
• SLWR design drivers
• Case study for Large OD SLWRs
• Installation considerations
• Cost considerations
• Summary
Risers in Deepwater North Sea

- Flexibles are the preferred solution
- Relatively shallow, low pressures and temperatures
- Good strength and fatigue resistance
- Can accommodate large motions; hence used with a wide range of FPS’s
- Limited to smaller size
- Not cheap
- Tendency to go with a solution that is widespread in the region
SCRs as an Alternative to Flexibles

- Mature technology
- Widespread use in GoM, Africa and Brazil
- Large ODs are feasible
- Limited by harsh environments
- Fatigue at touchdown is an issue
- Strakes needed for VIV suppression
- Installation costs can be high
- Track record in the North Sea
SLWRs

- Variation of SCR with buoyancy added
- Growing track record
- Reduced payload
- Sensitive to vessel motions at hang-off
- Buoyancy helps decouple vessel motions
- Improved strength and fatigue performance
- Large ODs are feasible ★
- Reduction in overall costs with use of large OD
- Higher installation costs depending on size
SLWR Design Drivers

- Offset range in extreme and survival conditions
- Vessel heave, pitch and roll motions
- Internal fluid variability
- Buoyancy length
- Payload

Acceptable levels of compression at sag bend

Acceptable stresses ratio along the riser for storm conditions

Small buoyancy section to reduce cost

Acceptable levels of bending at TDP

Riser must not touch the seabed
Case Study – Basis

• 850m Water depth
• 24” OD pipe
• Flex joint at hang-off
• Fluid: Gas and seawater
• FPS: Circular FPSO
• Top 250m straked
• Offset: 10% - Extreme, 12% - Survival
• Max 100yr return condition: 16m Hs
• Typical North Sea fatigue loading
• Strength and wave induced fatigue evaluated
Case Study – Selected Configuration

- Very flat configuration
  - Long step out distance
- High hang-off angle
  - Nominal – 18deg
  - Near – 14deg
  - Far – 22deg
- Long buoyancy Section
  - 122 modules, 2m each
- Top tension - 200mT
Case Study – Extreme Strength

- Stresses at the hang-off and touchdown are manageable
- Start of buoyancy section is critical
- Stress primarily caused by vessel pitch and heave motions
- Moving the hang-off closer to COG helps reduce motions
- High compression at sag bend; generally acceptable
Case Study – First Order Fatigue

- Wave fatigue is critical below the hang-off
- Higher quality weld is required
- Moving the hang-off closer to COG improves fatigue performance
- Long taper can help improve fatigue performance below hang-off
- Upset ends can be specified

<table>
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<th>DNV Curve</th>
<th>SCF</th>
<th>Target Fatigue Life (Years)</th>
<th>Minimum FOF Life (Years)</th>
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Hang-off closer to COG

Base Case Hang-off

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Case Study – Hydrotest

- Hydrotest is a known challenge for gas risers
- Buoyancy designed for gas filled case
- High pressure plugs can be used to hydrotest short sections
- Removable buoyancy modules to provide additional buoyancy during testing
Case Study – Pre-lay

- Pre-lay of SLWRs is important for schedule and costs
- Helps decouple FPS and riser schedule
- Riser typically installed empty
- Stresses in the riser are manageable
Installation Consideration

- Steel risers up to 16” (18”?) can be reel laid
- J-lay or S-lay preferred method for large OD
- J-lay limited by high stresses at TDP
- J-lay for large OD is possible with high inclination J-lay towers ★
- High quality welds difficult to achieve offshore
Costs Consideration

• SLWR Cost dependent on installation method
  • Reel-< J-< S-< lay
  • For large OD, J-<lay costs comparable to reel-<lay
  • Strakes and buoyancy modules add to installation costs
  • High quality welds done offshore adds to costs

• Flexibles vs SLWR vs Hybrid Risers
  • SLWR: Multiple wells tied back to a large OD riser reduces costs
  • Reel-<lay costs: Flexibles (20-30%) > SLWR
  • Hybrid riser costs are much greater than other options

<table>
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<th>Item</th>
<th>% of the Total Cost</th>
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<tr>
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<td>SCR/SLWR</td>
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<td>Material cost per riser</td>
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<tr>
<td>Installation and transportation</td>
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<td>Engineering, commissioning</td>
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Summary

• Flexibles are preferred in the North Sea; limited by qualified size

• Large OD SLWRs provide a viable lower cost solution compared to multiple smaller flexibles

• Tying back wells to a large OD SLWR reduces costs

• Reel-lay SLWR also provides lower cost solution for smaller diameters

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