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Selection and Optimization of FLNG Mooring Systems

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- Lessons learnt from Project Execution

Overview

- Introduction to Single Point Mooring Systems
- FLNG System Experience to Date
  - Several large-scale FLNG FEEDs / Project(s)
  - Medium - to small-scale FLNG FEEDs / Projects
- Key Components and Interfaces
- High-Level Design Basis for the Three Systems we have worked on
- Key Lessons Learnt
  - Focus on Pre-FEED and FEED Activities prior to Execution
- Summary

Introduction

- Over 150 FPSO/FSO Turret Mooring Systems installed
  - First turret moorings installed in mid 1980's
  - Wide range of water depths
    - 20 meters to 3,000 meters
- Turret Technology Development blossomed in the 1990's
  - Harsh environmental conditions
  - Large Turrets (>30 risers and umbilicals)
  - Disconnectable Turret Technology (e.g. Terra Nova FPSO)
  - Deep Water (>1,000 m)
- 2010's Turret / SPM Technology adopted for FLNGs
  - Prelude, PFLNG1, PFLNG2, Golar Hilli (SPM), ENI Coral South
- Key Turret Technology has a Well-established Track Record for Gas Service and Environmental Loads

FPSO Mooring Systems

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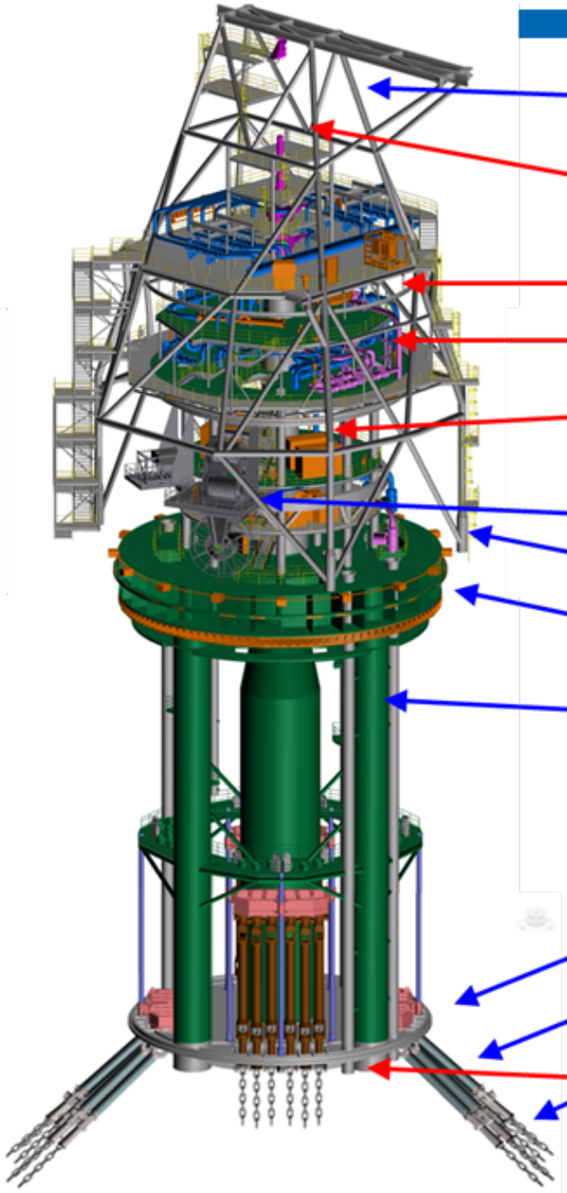
Turret Mooring System Components & Functionality



Swivel Access Structure

Swivel Stack

Pig Receiving Deck

Manifold Deck

Equipment Decks, Cabinets

Anchor Leg + Riser Pull-In Equipment

Riser Hang-off Deck

Wheel & Rail Bearing System

Lower Turret Structure

Chain Table & Lower Bearing

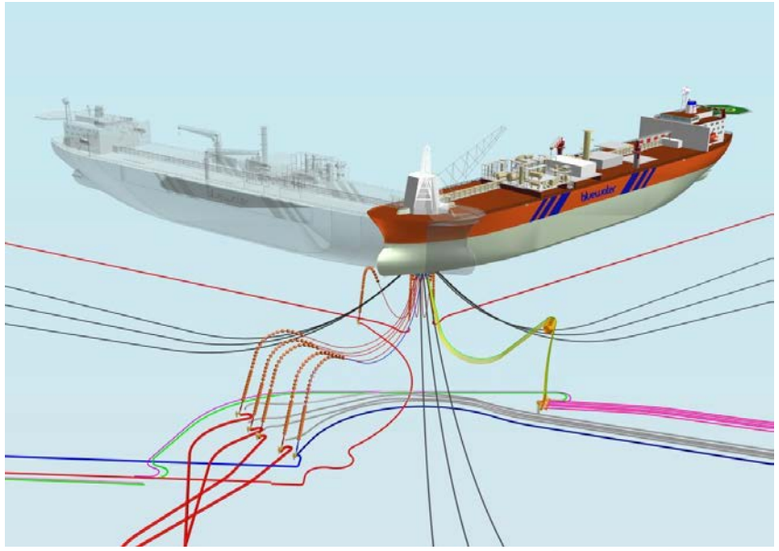
Chain Supports

Anchor Legs

Risers & Umbilicals

Fluid-Transfer

Load-Transfer



Courtesy Bluewater

Turrets for FLNGs

- Load-Transfer:
  - Smaller FLNGs are VLCC sized
  - Large FLNG Vessels: up to 500 m X 75 m X 45 m
  - Many in Harsh Environments (e.g. NW Australia)
  - Extreme Design Conditions (e.g. 10,000 year cyclonic storm)
  - Size / Weight of Turret / Vessel leads to Challenges in Integration (very dependent on Integration Yard Crane Capacity)
  - Large Number of Anchor Legs
- Fluid-Transfer:
  - Pressure and Fluid Control
  - Typically less complicated that a high-spec FPSO turret
  - Well within existing swivel technology
  - SURF Interface important
- Complex Project Structure and Interfaces
- Long Schedule – more like a Marathon than a Sprint!

Major Interfaces with Turret Mooring Systems

Turret Mooring System

Topsides
- Layout/Dimensions
- Requirements
- Safety Studies

Metocean
- Design
- Survival

Hull
- Dimensions and Mass
- Responses

SURF Package
- Risers
- Umbilicals
- Flow Assurance
- Controls, power, etc.

PFLNG SATU External Turret – delivered 2015

- 1.2 MTPA LNG
- 20-Year Life (Phase ~5 years; Phase 2 ~15 years)
- Offshore Malaysia, several locations
- 70 to 200 meters water depth
- Max. Hs ~ 8 m; Vw ~ 60 knots
- 3 x 4 Anchor Leg System
- Production Risers: 1 x 10” + 2 x 10” (future)
- Max. Design Pressure: 130 bar
  - Phase 1: 208 MMScfd; Phase 2: 230 MMScfd
- Multifunction Umbilicals (future): 3
- Turret Weight: ~1,000 MT

PFLNG DUA External Turret – delivered 2017

- 1.5 MTPA FLNG
- 500 to 1,500m water depth
- Metocean: Hs ~ 8m, Vw ~ 60 knots
- 3x4 Mooring System
- 4x10” Risers + 3xMF Umbilicals
- Total throughput 300MMScfd
- Incoming Temp. Range: -15 to 40 deg C
- ~2,000 bopd of Rich MEG injection
- HIPPS System (255 bar / 100 bar)
- First deployment: Rotan Field, ~1250m water depth
- Turret Weight: ~2,500 MT

Coral South FLNG Turret Mooring System

- 3.4 MTPA FLNG
- ~2,000m water depth
- Metocean:
  - 100YR: Hs ~ 13m, Vw ~ 33 m/s
  - 10,000Y: Hs ~ 17m, Vw ~ 50m/s
- 4x5 Taut Mooring System
- 8x9” Risers (6 + 2 Future) + 4xMF Umbilicals (3 +1 Future)
- Total throughput 600MMScfd
- Incoming Temp. Range: 7 to 65 deg C
- 30 m3/hr of Lean MEG
- 10 m3/hr of Total Water Production
- HIPPS System (400 bar / 143 bar)
- Turret Weight: ~8,000 MT

UNDER CONSTRUCTION

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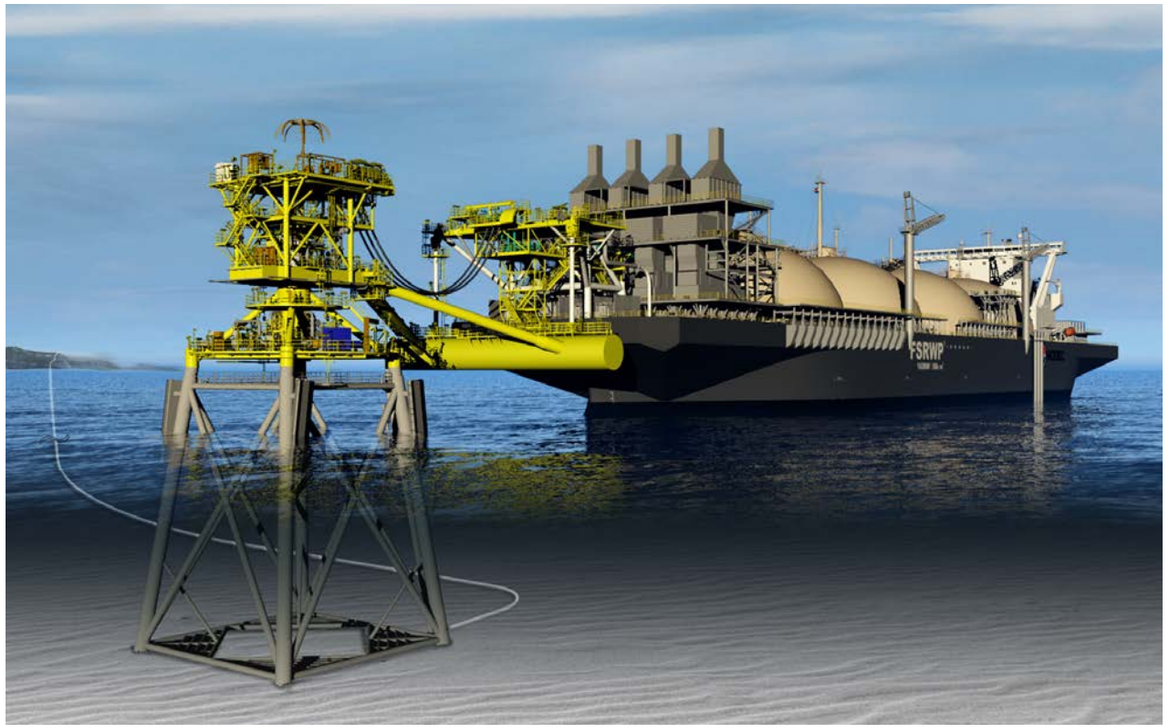
Use of Single Point Moorings in Shallow Water

PGN FSRU Lampung

- Water Depth: 23 m (Indonesia)
- Gas: 240 MMSCFD

MODEC FSR-Power Concept



- Water Depth: 18 – 35 m
- Power: Up to 400 MW / swivel
- Gas: 100+ MMSCFD
- Water: 60,000+ M^3/day

Critical Interfaces for a Turret Mooring System

Swivel Stack (SUBSEA, TOPSIDES, TURRET)

Turret Equipment Room (SUBSEA, TOPSIDES, TURRET)

To TOPSIDES (Production fluids, Data, etc.)

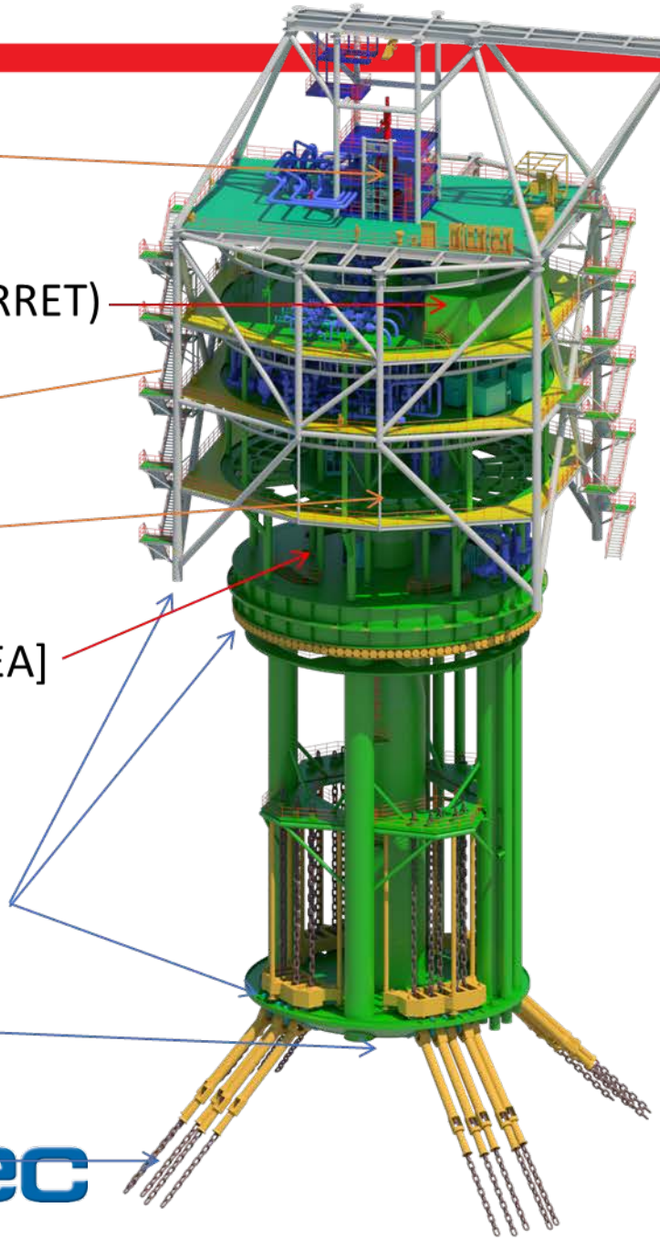
From TOPSIDES (Chemical Injection, Power, Instrumentation, Utilities, etc.)

Other Free-Issued Equipment [TOPSIDES /SUBSEA]

Integration [HULL / MOONPOOL / TOPSIDES]

Umbilicals and Risers [To and From SUBSEA, INSTALLATION]

Anchor Leg System [INSTALLATION]



Design Basis and Interfaces are Key!

- Design Basis: The Turret is key Interface between Topsides and SURF
  - Very little of the Fluid-Transfer basis is Turret specific…
  - Needs to consider topsides and SURF design philosophy and basis
  - Requires transparency and collaboration across various parties
  - Define specific project requirements in addition to Class / Regulatory requirements
    - Do not solely depend on a set of generic COMPANY / Contractor standards
- Interfaces:
  - Structural / Mechanical with Hull / Moonpool
  - Process Design Philosophy and Design Basis
  - SURF / Reservoir Design Philosophy and Design Basis
  - Topsides / SURF free-issued equipment
  - Mechanical handling and O&M Philosophy
  - Installation

COMPANY Technical Standards

- COMPANY Technical Standards versus Project Requirements
  - Typically meant to apply to all facilities and regions
  - Majority of documents to not apply to load-transfer components of turret
  - Can conflict with other industry standards or class requirements
  - Project team members may not have familiarity with them
- Review and eliminate un-necessary COMPANY documents during pre-FEED / FEED
  - Do not throw the entire stack “over the fence”
  - Leads to unnecessary debate / delays during project execution
  - Impacts both schedule and cost of projects
  - Is seen to be a project risk from a contractor / subcontractor perspective

Pre-FEED / FEED Execution

- Define during Pre-FEED:
  - Concept Selection
  - Vet / Challenge Basis of Design
  - Define interfaces and work them
  - Establish basis for FEED and clearly define objectives and establish schedule
  - Develop mechanism for optimization during FEED
- Detail during FEED:
  - Run Floater / SURF FEEDs concurrently or with SURF in advance
  - ***Collaborate:*** Build-in time and effort to allow for exchange between major contractors
  - Define stages or gates to allow option evaluation / definition of design basis
  - Evaluate COMPANY / other standards that add value to project and eliminate those that do not
  - FEED deliverables should be execution phase focused to allow proper contract definition and costs
- Execute during EPC
  - Minimize Change!
  - Execute as per FEED
  - Actively manage interfaces

Summary

- Turret Moorings are an Enabling Technology for FLNGs
  - Stationkeeping
  - Fluid-Transfer
  - SBS Offloading
- Draw on current available experience, standards and technologies from the FPSO industry where applicable
- Technology has been successfully applied to FLNGs
  - Two in Operation today (PFLNG1, Hilli); Prelude, PFLNG2, Coral South are in various stages of EPIC
- Focus on Turret Mooring System Definition and Optimization during FEED
  - More readily observed in small- and medium scale FLNG projects
- Develop a project structure and contract to allow optimization of interfaces across major components – especially during FEED
- Minimize Change during EPIC phase and Execute what is defined during FEED

Requires strategy and execution during pre-FEED / FEED

Thank You!

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Courtesy of Petronas