Flexible Riser Technology for FLNG Applications

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Subsea Asia Conference 2014
11th June 2014

Imagination at work
Agenda

› GE Oil & Gas Subsea Systems
› FLNG Market and Flexible Riser functional requirements
› Design challenges and solutions
› Manufacturing, Logistics and Integrity Management Solutions
› Conclusions
GE Oil & Gas overview
From extraction, to transportation, to end use ...

Gas Storage & Pipeline
On- and Offshore Oil & Gas Production
Offshore Drilling
LNG
Subsea
Services & Predictivity Skills Development
Distributed Gas
Refining & Petrochemical
Power Generation

Cutting edge technology & service solutions across the value chain

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GE Oil & Gas technology solutions

Subsea Systems
- Subsea trees & wellheads
- Subsea power & processing
- Controls
- Manifolds
- Flexible risers
- Flow lines
- Specialty connectors & pipes

Drilling & Surface
- Drilling risers
- Blow-out preventers
- Electric submersible pumps
- Logging while drilling & wire line tools
- Surface wellheads & flow control
- Logging services

Lufkin
- Artificial lift: rod lift, gas lift, plunger lift, progressive cavity pumps, hydraulic pumping units
- Service & repair
- Engineered industrial gears
- Fluid film bearings

Measurement & Control
- Asset condition monitoring, control sensing & inspection solutions
- Optimization & diagnostic software
- Pipeline inspection and integrity services
- Control & safety relief valves
- Fuel dispensers & payment terminals
- Fuel control & retail systems

Turbomachinery Solutions
- Gas turbines
- Axial & centrifugal compressors
- Electric motor driven compressors
- Turn-key industrial modular solutions
- Turboexpanders & heat exchangers
- Contractual & maintenance services
- Upgrades & industrial applications
- Monitoring & diagnostics

Downstream Technology Solutions
- Steam turbines
- Reciprocating compressors
- Distributed gas solutions – small LNG & CNG
- Pumps, valves & distribution systems
- Blowers & compressors
- Maintenance services & remote monitoring & diagnostics

~45,000 employees
~$17B revenues ’13

Delivering customer solutions by applying systems-level engineering across the portfolio

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GE Oil & Gas Subsea Systems Product offering

Trees
Power & Processing
Offshore
Manifolds
Controls
Flexibles
Services

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Subsea Systems at a glance

Global footprint

7,000+ employees globally

Europe ~4,000
North America ~370
Latin America ~1,800
Africa ~240
Asia Pacific Australia ~540

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Simplification is also ‘localization’
More complex, difficult and remote projects require a local presence and local decision making.

2013 facility openings in Indonesia, Brazil, the UK and Vietnam

Our global footprint speeds and improves delivery of services, technologies and expertise – $1B+ in capacity and capability added in 2013
Flexible Riser Technology for FLNG Applications
There are 27 current or planned FLNG projects worldwide up to 2023.

12 of these projects are in Asia-Pacific, including:

- Shell Prelude
- Petronas Kanowit
- Murphy Block H
- INPEX Abadi
- Woodside Browse
- GDF Suez
- Bonaparte ...

Flexible risers are an existing and proven technology which offer significant benefits for floating production.

For FLNG projects flexible risers are for production and export applications rather than transfer of LNG.
FLNG Risers: Functional Requirements

FLNG production and export risers are typically characterised as follows:

- Internal diameter: 10 to 16 inch
- High fluid velocity: circa 30 m/s
- Internal design pressure: 300 to 450+ bar
- Internal design temperature: -35 to 130°C
- Water depth: 200m to 1,300m+
- Design life: 25 to 40 years
- Insulation: 0 to 5 W/m2K
- Moderate levels of H2S (circa 50 to 100ppm)
- High levels of CO2
- High levels of sand production

Demands close attention to flexible pipe system design, manufacturing, logistics and Integrity Management
Design Challenges and Solutions
Design Focus Areas for FLNG Risers

1. **Internal Carcass:**
   Sand erosion at high velocities over long service life

2. **Pressure Sheath:**
   Low to high temperature thermal cycling

3. **Pressure and Tensile Armour:**
   High pressure, sour service

4. **Anti-Wear Tapes:**
   Degradation resistance

5. **Riser System Design:**
   Extreme loads, interference, fatigue
Internal Carcass  
Collapse Prevention

Scale Formation

- Presence of high levels of CO2 and water vapour creates a corrosive environment of carcass
- Duplex stainless steel is an effective and proven solution

Erosion Process

- FLNG projects typically have high levels of produced sand with high fluid velocities and long service life
- Over time carcass material is eroded when impacted by sand particles
- GE has completed an erosion testing campaign dedicated to high velocity gas flows with low liquids content
- Testing performed on a large diameter full scale sample at its minimum bend radius
- Sand velocity representative of typical FLNG conditions
- Results used to further calibrate design methodology
Pressure Sheath
Fluid Containment

Low to High Temperature Thermal Cycling

- High temperatures challenge the upper limits of polymer capacity
- Pressure sheath creep into pressure armour layer becomes more pronounced with increased pressure, temperature and service life
- Critical control of barrier nub profile is achieved through production
- Low temperatures typically occur in start-up and shut-down conditions
- Thermal cycling testing performed to confirm pipe and end-fitting sealing integrity when subject to temperature changes
- PVDF thermal shock testing performed
Pressure and Tensile Armour
Static and Dynamic Load Resistance

Requirement for large diameter pipe at high pressures
Pressure and Tensile Armour

Static and Dynamic Load Resistance

FLNG demands combination of high pressure and large inner diameter:

- Most challenging known requirement is 12” ID / 450 bar which is within the qualified range of flexible risers

Achieved through:

- High capacity pressure armour layer(s) for hoop strength
- High capacity tensile armour layer(s) for axial strength (including compression)

H₂S in annulus generally necessitates reduced strength wires:

- Realistic approach to permeation and H₂S effects
- Qualification of high yield strength materials for sour service
- High pressure, large diameter risers can accommodate >100ppm H₂S

Extended service life raises challenges with respect to wire:

- Fatigue resistance
- Corrosion resistance
Anti Wear Layer

Interlayer Friction

Tape layers applied between any two adjacent metallic layers, to avoid metal to metal contact and to control tensile layer buckling

Key challenges:

• High interlayer pressures require high strength materials
• Longer design life (up to 40 years)
• High temperatures accelerate degradation
• Materials need to be compact and cost-effective

Extensive material qualification of:

• PVDF/PTFE tape (high contact pressures/temperatures)
• PEEK/Crystalline Polymer Wrap (Extreme temperature/contact pressures)
• Aramide Fibre Tapes (high temperature/strength)
Riser System Design

Global Analysis

Manage Extreme Loads:
- 10,000 year wave and current conditions
- Survivability in cyclonic conditions
- Variance in risers contents density, marine growth
- High pressures and temperatures effect on pipe stiffness

Mitigate Interference:
- Riser – Riser
- Riser – Mooring
- Riser – Vessel

Evaluate Fatigue:
- Long design life in challenging environment
- Vortex Induced Vibration (VIV) effects

Prelude FLNG (Sources: GE & Shell)
Manufacturing, Logistics and Integrity Management Solutions
Manufacturing and Logistics

Large diameter (and potentially insulated) pipes for high pressure service have a large bending radius.

Benefits of single piece risers can include:
- Reduced engineering and manufacturing costs
- Efficiencies in installation
- Removal of splices and reduction in leak paths
- Improved long-term integrity

Necessitates high volume manufacturing, packaging and transportation solutions:
- Larger reels (35’ to 40’)
- Carousels: manufacturing, transportation and installation
- Heavy lift capacity (300Te to 450Te)
Integrity Management

Monitor Asset integrity

Flexibles are inherently designed to be maintenance free

Advancements in monitoring technologies allow Operators to gather a detailed picture of service history, prediction of future performance and remaining service life

Potential to reduce operational, safety and environmental risks by using the data collected to:

- Maximise the time to plan interventions
- Maximise asset life and production availability
- Minimise cost by allowing predictive maintenance

Range of products and services are offered:

- Distributed temperature sensing (DTS)
- Breach detection
- Curvature monitoring
- Annulus condition monitoring
- MAPS™ Armour wire stress monitoring
Conclusions
A Robust, Proven Solution for FLNG

- Flexible risers have a proven track record spanning many decades
- Significant further testing and development in recent years has addressed some of the key design challenges of FLNG projects
- Investment in manufacturing and logistics solutions offer cost and time savings to projects in the fabrication and offshore phases
- Development of integrity management technologies allows Operators to understand service history, future performance and remaining service life
Further Technology Development

- GE Wellstream focused on delivering solutions for further advancements in flexible riser technology
- Purpose built Flexible Pipe Innovation Centers:
  - Niteroi, Brazil
  - Newcastle upon Tyne, UK
- Leveraging GE global leading R&D capabilities
- Next generation of flexible pipe materials
- Deeper water applications; 3,000m+
- Higher pressures and temperatures