Refrigeration Compressor Driver Selection and Technology Qualification Enhances Value for the Wheatstone Project

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Topics

• Project background
• Driver alternatives
• Driver selection
• Technology qualification
• Conclusions
Project background
Wheatstone Project

- 2x4.45 MMTPA LNG Trains
- 0.2 BCFD Domestic Gas Plant
- 44” Export Pipeline 225 km to Plant
- 1.6 BCFD Subsea Wells & Facilities (Chevron / Shell)
- 0.4 BCFD Subsea Wells & Facilities (Apache / Kufpec)
- 2.0 BCFD Processing Platform 73m water depth
Plant location

• Ashburton North Strategic Industrial Area
• Located about 12 km SW of Onslow
  ▪ Population about 450, increasing to 650 in winter
  ▪ Primary industries agriculture (sheep), salt (Onslow Salt) and fishing
Onshore facilities

- 2 x 4.45 mtpa LNG trains; Condensate and domestic gas production
- ConocoPhillips Optimized Cascade® process
- Modular construction strategy
- 2x150,000 cum FC LNG tanks
- USD 29 billion investment
- Planned expansion to 25 mtpa of LNG
Driver alternatives
Evolution of drivers in LNG industry

- Steam Turbine Drivers
- Gas Turbine Drivers
- Electric Drivers

Startup Year

Plant Location

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First application of gas turbines

Kenai LNG – First Application of Gas Turbines in LNG Service (1969)
Project specific factors influencing driver selection

Key project specific factors influencing driver study

✓ Fixed feed stream flow limiting ability to utilize excess driver power

✓ Compositional uncertainty with regards to feed stream nitrogen content requiring flexibility with available power

✓ Site ambient conditions; ambient temperature ranging from 13°C to 40°C (extremes 5°C to 47°C)

✓ Other criteria for selection include emissions, total installed cost, LNG Production, operating cost, technical/operational/schedule risk, etc
Driver study alternatives

i. 6 x LM2500+G4 with mechanical refrigeration for inlet air chilling (IAC)

ii. 6 x LM2500+G4 with Inlet Air Humidification (IAH)

iii. 7 x LM2500+G4 with no power augmentation

iv. 6 x LM6000PF with IAH

v. 7 x LM2500+G4 with IAH

vi. 7 x LM2500+G4 with IAH and HRSG and steam turbine power generation

vii. 2 x Frame 7EA and 2 x Frame 5D
Selected driver – LM6000PF

- 6 x LM6000PF with IAH was the selected based on a combination of low TIC, attractive NPV and DPI

- Technical risk managed via a technology qualification plan

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Description</th>
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<tbody>
<tr>
<td>i</td>
<td>6xLM2500+G4 with IAC</td>
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<tr>
<td>ii</td>
<td>6xLM2500+G4 with IAH</td>
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<tr>
<td>iii</td>
<td>7xLM2500+G4 with no augmentation</td>
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<td>7xLM2500+G4 with IAH</td>
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<td>vi</td>
<td>7xLM2500+G4 with IAH and Steam Cycle</td>
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<tr>
<td>vii</td>
<td>2xFrame 7EA</td>
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Technical qualification

LM6000-PF
15 ppm
Chevron Technology Qualification Process

• Formal methodology and toolbox of resources
• Joint effort between Chevron, Bechtel, GE and CoP
• Identified systems/sub-systems for qualification
• LM6000 TQP completed in December 2009
Major TQP Activities/Findings

• Dynamic Simulations
  ▪ Train shut-down and startup simulation by Bechtel
    ✓ The compressor train takes over 20 seconds to decelerate to approximately 1800 rpm
  ▪ LM6000PF engine simulation during train shut-down by GE using their engine simulator
    ✓ Gas turbine can stop in less than 5 seconds without stall occurring within the axial turbine.

• Compressor selections for the base case design operating conditions

• Compressor capable of full pressure restart

• Train Torsional Analysis for the Methane compressor train
Conclusion
Technology Qualification Conclusions

- All major TQP risks and open action items have been addressed and closed
  - Design review
  - Modeling and Simulations
  - Quality control/inspections
  - Testing at Supplier Facilities
  - Field inspection and testing
  - Gas Turbine Performance Testing
  - Full load string testing

- LM6000PF – acceptable mechanical drive option for Wheatstone
Questions
Ambient temperature impact on gas turbine performance

Gas Turbine Lapse Rate versus Ambient Temperature (new and clean)

- LM6000PF
- LM6000PF w/Evap Cooler
- PGT25+G4
- Frame 6B
- Frame 7EA
High ambient temperature operation options

- Overfiring of gas turbines
- High purity refrigerant propane
- Add sprint to propane LM6000 gas turbine
- Inlet mechanical chillers
- LiBr chiller package
- Helper motor for propane compressor gas turbine
- Compressor impellor technology with higher turndown capability