Operational Experience with LM6000 PF Aero-Derivative Gas Turbine in Mechanical Drive Service at Wheatstone LNG Facility

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Topics

• Background
• Operation with dry low emissions (DLE)
• High ambient operation
• Variable speed operation
• Control systems
• Planned maintenance
• Conclusion
Background

- 2 x 4.45 mtpa LNG trains; Condensate and domestic gas production
- ConocoPhillips Optimized Cascade® process
- 2 x 2 x 2 LM6000PF selected as mechanical drivers for refrigeration compressors based on attractive NPV and DPI
- Large range of ambient temperature variation
Background – Refrigeration Compressors

- Full load full speed string test conducted for the methane compressor string
- Operational lessons incorporated from other aero-derivatives and other LM6000 facilities to improve reliability prior to startup
- Significant integration between the Licensor, EPC contractor, equipment supplier and end user throughout the design, construction, commissioning and startup to manage risk
- Technical risk of first refrigeration compressor mechanical drive application for LM6000’s managed via a technology qualification process and risk mitigation plan
Operation with Dry Low Emissions

- Large variation in fuel gas nitrogen content and associated rate of change considered a significant project risk
- Designed with Wobbe meters and active fuel control to meet 10% modified Wobbe Index per minute rate of change.
- Significantly higher rates of change managed by the fuel system in actual operation
- Site specific DLE mapping procedures and significant onsite operational capability developed to minimize risk
High Ambient Operation

- New impellers selected to give a wider range of turndown for high ambient conditions
- Capability to over-fire the gas turbine included, but not utilized in practice
- Noise in flow signals influenced the ability to reduce flow on the compressors
- Ability to balance refrigeration loads allows operation through high ambient conditions
- Upgraded LM6000PF+ engines on Train 2 greatly improve operability at high ambient conditions
- Evaporative cooling significantly reduces the range of DLE mapping for the gas turbine

% Exceedance | 0.05% | 1% | 5% | 50% | 95% |
---|---|---|---|---|---|
Case | Extreme-High | High-High | High | Average | Low |
Temperature (°C) | 46.0 | 39.6 | 35.1 | 25.3 | 15.2 |
Relative Humidity (%) | 15.0 | 31.6 | 58.1 | 81.8 | 92.1 |
Start-up and Variable Speed Operation

• Able to start from full settle out conditions
• Sump pressurization and evacuation systems are used during the starting sequence
• Compressor anti-surge valves preposition and start controlling during the start sequence
• Proven ability to handle variable speed applications during process and load transients
Control Systems

- Mark VIe control system utilized to match other controllers in the business unit
- Provided flexibility for the active fuel control
- Detailed testing of controls systems including negative testing of all function was highly valuable
- New controls had a series of minor issues that were solved during the commissioning phase
- Working relationship to solve issues was very strong throughout the project and continues into operation
Planned Maintenance

• Project was based on maintenance intervals that included off-line water wash and daily on-line water wash
• F9 pulse pre-filters and E10 HEPA filters were included
• Water washing has not been required as a result of the filtration and evaporative cooling system.
• Extending borescope inspections to 8k hours
Conclusions

• Technical risks addressed by the risk management and qualification plan
• Developing operational capability related to DLE systems and controls was critical to success
• Use of HEPA filters and evaporative cooling has significantly reduced the required planned shutdowns for off-line water washes
• The use of PF+ gas turbines is improving operability of the facility in high ambient conditions
• Excellent collaboration between all parties has driven the successful first application of LM6000 mechanical drives