Floating gas liquefaction: competing technologies make progress

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Offshore LNG has different process requirements than liquefied propane gas (LPG) or traditional on-land, base-load liquefication plants. To satisfy key LNG requirements for remote, offshore environments, three generic technology options are being put forward.

LNG Floating Production Storage and Offloading (LNG FPSO) has been the focus of research and development since the 1980s, but in 2008 took a step toward deployment with the commitment by FLEX LNG Ltd. to construct vessels for service offshore Nigeria and Papua New Guinea.

Samsung Heavy Industries Co. is the main engineering contractor for the LNG Producer (LNGP). The first vessel (LNGP 1) is under construction in South Korea, and long-lead compression equipment for the 1.7 million ton per annum (mtpa) LNG FPSO topsides plant is on order. Norway's Kanfa Aragon was contracted in January 2009 to provide the topsides based around an optimized dual nitrogen liquefaction process technology. The vessel, to be deployed offshore Nigeria, is scheduled for operations in 2012.

Also in mid-2008, Japan's Inpex Corp. submitted a development plan to Indonesian authorities that included a 4.5 mtpa LNG FPSO option to develop its 10 Tcf Abadi field in the Masela block close to the border with Australia. Negotiations continue regarding a potentially costly Abadi LNG FPSO project, with the potentially less-expensive alternative of piping gas to a land-based liquefaction plant in Australia not acceptable to Indonesian authorities.

More recently, in April 2009, Norway's Höegh LNG announced completion of its LNG FPSO FEED Project conducted in collaboration with CB&I Lummus for the topsides design and the liquefaction technology (i.e. their NicheLNG liquefaction process , which received the American Bureau of Shipping (ABS) approval in principle for its use on an FPSO in February 2005) and Daewoo Shipbuilding & Marine Engineering (DSME) for the hull design. That nine-month FEED project followed on from a six-month pre-FEED project completed by Höegh LNG in March 2008 in conjunction with Aker Yards and Lummus based around a Q-Flex size vessel. Annual production capacity for the FPSO was focused on 1.6 and 2.0 mtpa of LNG costed in the pre-FEED at between $700 and $1000 per tonne of capacity along with 400,000 tonnes of natural gas liquids. Final investment decision is pending for Höegh LNG FPSO, but a specific field development project is yet to be announced. Earliest deployment could be 2012.

In response to such developments, Shell, the company that has been most associated with evaluating potential LNG FPSO projects the past twenty years, during 2008 reaffirmed its continued pursuit of LNG FPSO opportunities.

Shell is considering LNG FPSO projects offshore Egypt, Iraq, and Australia for facilities in the 2 to 6 mtpa capacity range, but as yet has made no firm commitments. In July, the company announced a tender for front-end engineering and design (FEED) and engineering procurement & construction (EPC) contracts for a 3.5 mtpa capacity LNG FPSO, with a deck area, to contain its proprietary liquefaction process technology, of 450 m by 75 m.

With this renewed impetus, LNG FPSO technology and development issues are receiving attention from companies and governments holding stranded non-associated gas assets, or wrestling in the wake of no-flaring rules with how to handle large volumes of associated gas in large remote oil field developments.

Risks and rewards

Besides assessing risk—technology-, safety-, and environment-related—challenges to LNG FPSO deployment include construction and operating costs, unexpected downtime, volatile LNG prices and demand, politics, and extreme weather, not to mention persuading investors that LNG FPSOs offer the best development alternative for stranded gas assets.

Thus, the difficult hurdles are not now likely to be only technical. Historically, governments and labor unions have remained skeptical of the long-term value of facilities that sit over the horizon and can be removed at short notice. Many prefer land-based liquefaction plants and the greater contributions these will make to their broader industrial and social economies.

However, some now realize that remote and dispersed gas assets are unlikely to justify the financial and environmental burdens that large, land-based liquefaction plants involve. In this regard, in 2008, the Indonesian government appears to have shown more enthusiasm for LNG FPSO options than the associated operating companies.

The closest vessel to an LNG FPSO currently in operation is the Sanha LPG FPSO operated by SBM Offshore for Chevron as part of a gas condensate field development offshore Angola, commissioned in 2005 and built in Japan by IHI Ltd. It consists of six IHI-SPB (Self-supporting Prismatic shape IMO Type-B) tanks of low-temperature steel providing 135,000 cu m LPG storage in total. Process equipment includes depropanizer, liquefaction, and reliquefaction units integrated with the LPG process plant.

The vessel also includes a nine-story accommodation block with helipad to accommodate 60 crew members, and an external turret to moor the vessel and connect a flexible riser to the seabed. The LPG offloading system involves both side-by-side and tandem alternatives. An aft thruster minimizes wave-induced vessel motion. LNG FPSOs will need to incorporate most of these features.

A different breed

Offshore natural gas liquefaction has different process requirements than LPG or traditional on-land, base-load liquefaction plants. Thermodynamic efficiency is the key technical process selection criteria for large onshore natural gas liquefiers. Hence, high-efficiency, pre-cooled mixed refrigerant (C3/MR) and optimized cascade (multiple refrigerant cycle) plants dominate onshore base-load liquefaction plants. However, such technologies only make commercial sense for large-capacity LNG FPSOs (i.e. > 3 mtpa) and in many cases do not best satisfy key requirements of remote offshore environments.

Three generic technology options with quite distinct efficiency and complexity characteristics are being progressed, including dual-mixed refrigerant, nitrogen single- and dual-expanders, and single-mixed refrigerant (Figure 1):

Dual-mixed refrigerant (DMR). Russia's first land-based LNG plant (Sakhalin II) is due to deliver its first LNG in early 2009. That plant uses Shell's DMR process, focused on efficiency over a wide range of local temperatures (i.e., +30°C to -30°C). Increasing the proportion of propane creates a heavier refrigerant mix for the first cycle in summer (cools gas to -40°C), while adding ethane yields a lighter mix for winter (cools gas to -65°C). Traditional C3/MR pre-cooling cannot be adjusted this way and is best suited to large-scale plants in equatorial conditions.

Shell compacted its DMR technology to enable medium-to-large scale offshore operations—i.e. Shell Automated Cool-Down (SACD). This involves refrigerants mixes lighter than propane, used to reduce the risk—associated with the potential for refrigerant leaks—of liquid pools forming. The SACD technology makes the cool-down process more efficient, placing less stress on the main cryogenic heat exchangers (MCHE).

Nitrogen single and dual expanders. In contrast to large-scale liquefaction processes using either mixed-refrigerant or pure-component cascaded refrigeration cycle, expander-cycle technologies use all gas (or mostly gas) refrigerants. Although less efficient, the expanders offer many benefits for small-to-medium scale offshore liquefaction. The working fluid in the expander refrigeration system is typically nitrogen.

Used mainly for small-scale, < 0.5 mtpa applications, such as peak shaving and liquefaction of boil-off gas, several technology providers have variations on single expander technology that improve efficiency by either using two expanders (some with hydrocarbon gas, usually methane, in one expander), adding a pre-cooling cycle, or expanding a saturated LNG product in controlled stages.

To achieve more than 1 mtpa capacity, most expander technologies require more than one train, which adds to the rotating equipment count. FLEX LNG has opted to use Kanfa Aragon’s dual nitrogen turbo-expander liquefaction technology for LNGP 1. Compared with the dual nitrogen loop, the CB&I Lummus NicheLNG replaces one Nitrogen loop with a methane (process gas) loop resulting in a higher efficiency. Regardless of the refrigerant used dual loop liquefaction technologies all involve dual expanders and multi stage compressors. and are more efficient (i.e. efficiency range ~89% to 92%) than single nitrogen loops (i.e. efficiency range ~80% to 85%).

Single-mixed refrigerant (SMR). This is an intermediate solution between that offered by expanders for small plants or using two or more cycles of mixed refrigerants in large plants. A single cycle offers a trade-off between efficiency and simplicity, including use of tried and tested technology. SBM/Linde offers for 2013 delivery an LNG FPSO with SMR process technology, 2.5 mtpa production capacity, and 230,000 cu m storage capacity—consisting of 180,000 cu m LNG, 25,000 cu m LPG, and 25,000 cu m condensate. SBM/Linde completed a full FEED study of their LNG FPSO concept in September 2008, which suggested some 15% to 25% efficiency gains on dual- and single-nitrogen expander plants. That still leaves it up to 5% less efficient than dual-cycle mixed-refrigerant plants. However, its single-train design offers substantial savings in terms of rotating equipment count and costs.

Based on the foregoing discussion, it’s possible to conclude that appropriate LNG process technology for an LNG FPSO depends mainly upon required liquefaction capacity, itself dependent upon field reserves and production rates, as well as environmental requirements at each location. Further, significant competition is expected among the LNG process technology providers over the next few years. The onus is very much on them to justify the comparative efficiencies, reliabilities, and advantages of their offerings.

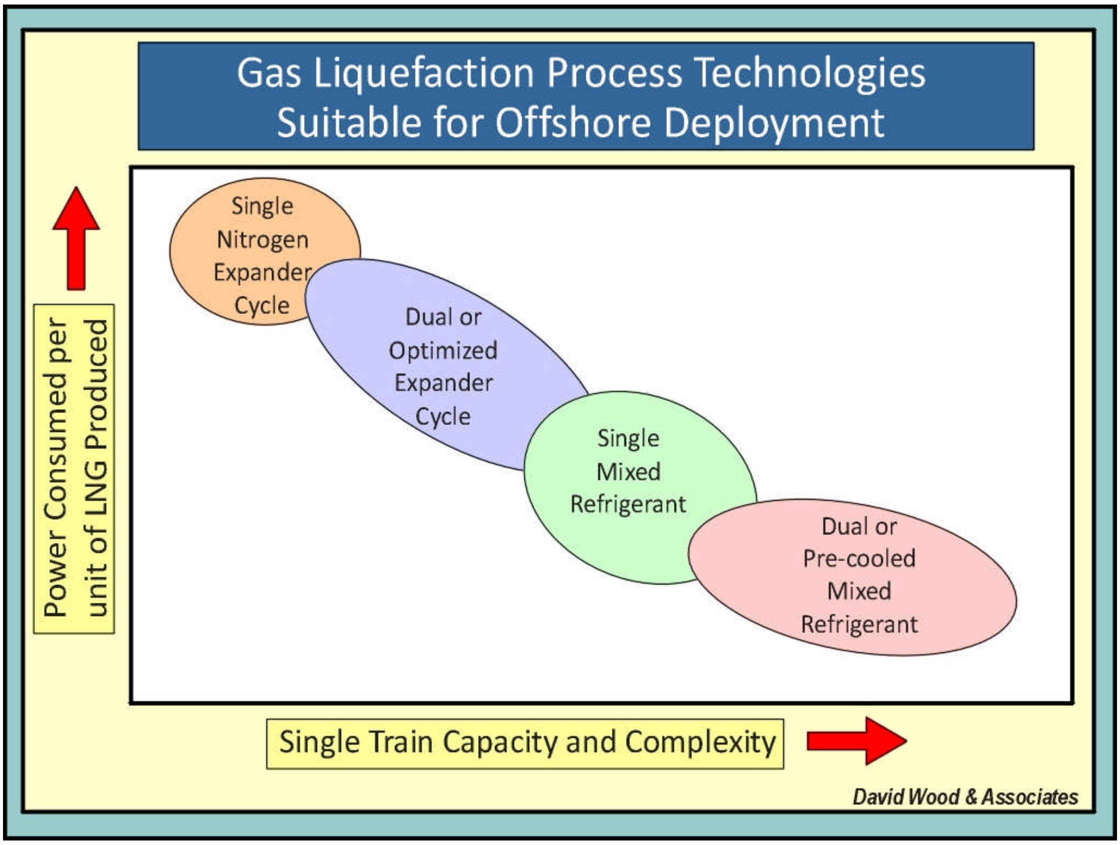

Figure 1. Efficiency and complexity of gas liquefaction process technologies proposed for offshore deployment qualitatively compared.

Sidebar:

LNG floating Production Storage and Offloading (FPSO) process criteria that impact the design agenda included the following:

- process, storage, and offloading safety
- low weight
- compactness
- simplicity of operation (high uptime)
- process efficiency
- production rate flexibility
- Capable of handling a wide range of feed gas compositions

- Options to recover LPG and NGLs as part of the FPSO topsides processing
- low equipment count
- small operating crew
- modular design
- stable decks (robust to vessel motions) minimizing weather-related downtime
- storage unaffected by sloshing impacts
- quick start and shutdown capability
- low requirements for handling hazardous refrigerants (high inherent process safety)
- High energy efficiency
- facility security

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