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FLNG: applying advanced technology to bring more natural gas to market

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Background

Global population is continuing to grow and is expected to reach 9 billion by the middle of the century, some 2 billion more compared to current levels. With urbanisation also continuing and hundreds of millions of people moving out of poverty in emerging economies, the desire for energy will grow accordingly. Consequently, the International Energy Agency believes demand for energy to double by 2050 from its baseline in 2010.

To meet the world's growing energy demands, bringing new supply sources to market is critical. Gas resources are plentiful and geographically diverse and we see a strong demand for natural gas – the cleanest-burning fossil fuel. However we will need increasing advances in technology to economically and efficiently bring this gas to the people that need it.

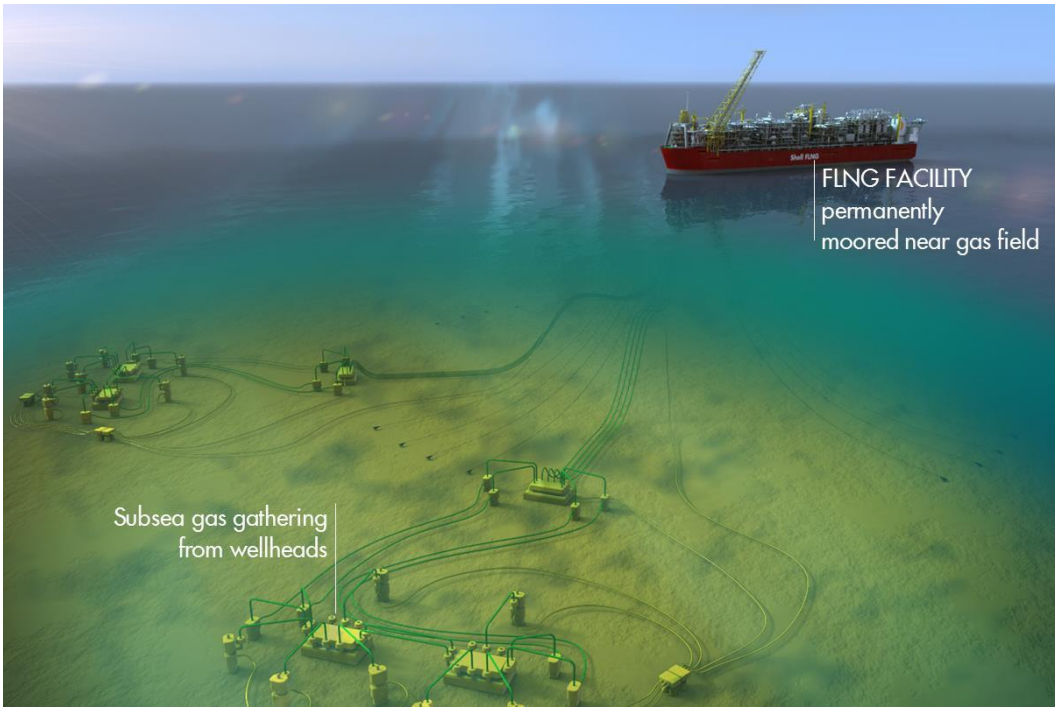
Shell, with a history in LNG spanning 50 years, has become the world's largest international oil company by equity LNG production with ownership in many liquefaction projects currently in operation or under construction. Our Floating Liquefied Natural Gas (FLNG) journey started in the 1990s with early stage project development followed by further design work. We embarked on the FLNG journey as we believe that this technology will open up new business opportunities for countries looking to develop their gas resources and bring more natural gas to market. We are now successfully executing the Prelude FLNG project and working further partnerships and plays for future projects.

Aim

The FLNG technology allows for the production, liquefaction, storage and transfer of LNG at sea. We believe FLNG is complementary to onshore LNG and as such aims to provide a new and additional method of developing and bringing offshore gas resources to market.

Shell's final investment decision (FID) for Prelude in May 2011 was the world's first FID for a FLNG project. Shell is the operator of Prelude in a joint venture with INPEX (17.5%), KOGAS (10%) and OPIC (5%).

Shell's FLNG facility itself is large, but is still one quarter the size of an equivalent facility on land. The key components of a FLNG development include standard gas field components such as production wells, subsea templates and risers and the floating facility itself. The facility is a full production facility with living quarters, gas processing, treatment and liquefaction facilities, product storage and offloading facilities, all integrated in a single facility. All processing operations are carried out offshore with LNG, LPG and condensate product exported to tankers directly from the facility.



FLNG Development Layout

Once constructed, the FLNG facility will be towed to the field site where it will be moored for the duration of operations – approximately 20-25 years – without being disconnected. Shell's facility has been designed to withstand extreme weather, including 1 in 10,000 year events, and will remain on location during all conditions.

In parallel to constructing the Prelude FLNG facility, Shell has also developed a solution to allow for robust and economic development of gas fields with low liquid (i.e. condensate and LPG's) content, called FLNG Lean. The aim of maturing this concept was to have a FLNG development concept with a higher LNG production and reduced liquids handling functionality, whilst maximizing the similarities and synergies of replication a Prelude type of FLNG design.

Methods

The development of FLNG is complex. Shell has been working on FLNG technology since the mid 1990s, drawing on more than five decades of expertise in LNG technology, LNG shipping and operating offshore oil and gas installations. Shell's approach to FLNG is to design for safe, high availability and reliability, by using proven technologies. The constraints of space and seaworthiness however, required the designers to assemble them in novel configurations.

Turret

Shell's FLNG employs an internal turret. All the subsea connections join the facility via the turret. Production wells on the seabed feed gas and condensate from the reservoirs through a number of flexible risers and a standard fluid transfer system (swivel stack) into the facility. The internal turret was selected as it is more suitable for fields that require larger and more complex subsea systems and a large number of risers. Internal turrets are also better suited for harsh metocean conditions.

Hull

A double wall substructure carries the topsides and the turret mooring system. It hosts the LNG, LPG and condensate storage tanks, the water production units (potable water, process water, and boiler feed water), waste water treatment facilities and several facilities for intermediate storage, maintenance and operations. The hull of the facility is designed to have a 50-year life. The FLNG product containment system is based on existing LNG containment systems but designed to withstand liquid motion, or sloshing, forces when only partly full.

Processing Equipment
Major processing equipment such as the absorption columns and the main cryogenic heat exchangers have been 'marinised', to allow them to operate efficiently under marine conditions. FLNG will use Shell's proprietary double mixed refrigerant (DMR) process to liquefy the gas. Shell DMR is a flexible process that uses mixed refrigerant for pre-cooling and the liquefaction cycles, enabling full power utilization over a wide ambient temperature range.

Cooling Water
Specially designed cooling water risers will draw water from deep in the ocean to be used in the LNG process. Process efficiency is increased by the cooler water. Over 50 000 m3/h will be drawn from 150 metres below the facility, where the water is about 10C lower than the surface water temperature.

Product offloading
LNG and LPG will be offloaded via a side by side vessel configuration using an offloading system developed from conventional LNG loading equipment. This system of specially designed cryogenic loading arms makes allowance for the fact that both the facility and product carrier will be moving. Thrusters at the stern of the facility may also be used to position the FLNG facility to facilitate the offloading process.

Safety by design
The safety of the FLNG facility has been foremost during its design, and its safety is on a par with modern offshore oil and gas facilities. Process safety has been the single most important driver for developing the facility layout. Formal Safety Assessments Quantative Risk Analysis (QRAs), performed at different design phases of the project have been used to evaluate layout options and rigorous process safety standards have been applied throughout the design process.

The overall aim is not only to reduce the risk for personnel operating the facility but to also be able to demonstrate that the design choices made satisfy 'As Low As Reasonably Practicable' (ALARP) criteria. The living quarters, the helipad, the control room and the workshop are located at the back of the FLNG facility. These areas, where more people may be working or resting are, by design, furthest away from the turret and processing facilities where there are large, high pressure inventories of gas, and separated by relatively low risk equipment and utilities in between. There are also 20 metre safety gaps across the full width of the FLNG barge between adjacent processing modules. On the barge deck and the main process deck, escape routes are provided at both starboard and port side, running along the full length of the FLNG facility. The central alley between the port and starboard side modules provides a third escape way on the process deck level

FLNG LEAN

FLNG Lean is built off the same platform as the Prelude FLNG project and is designed incorporating lessons learned, and technology development since the start of the Prelude project and other design studies. Where possible, technology designs are copied from Prelude, such as the hull, accommodation, operating and safety philosophies, flare and blow-down and cooling water systems, enabling maximum repeatability. To create sufficient deck space for the liquefaction trains and process equipment, some utilities have been moved into the hull. Aero-derivative gas turbines will drive liquefaction compressors and generate power. All process heating requirements will be met by waste heat recovery units. The FLNG LEAN design does not cater for LPG product storage and offloading and the freed up storage capacity is used for additional LNG storage.

The FLNG LEAN design production capacity is more than 6 million tonnes per annum. Under some circumstances and dependent on the specific characteristics of the field, we could consider expanding this LNG capacity even further.

Results

Delivering FLNG successfully is dependent on strong partnerships. The development benefits from the long term partnership established with the Technip-Samsung Consortium to design and build multiple FLNG facilities.

Prelude Progress

Prelude is a global project, with fabrication of the components happening around the world. A key location is South Korea, where the Prelude FLNG substructure and topsides are under construction in the Samsung Heavy Industries (SHI) shipyard on Geoje Island. In May 2013, the keel was laid in the dry-dock. And then on November 30th 2013, just 14 months from first steel cut, Shell and its partners celebrated the floating of the biggest hull ever built. The hull will remain floating alongside a quay in the SHI shipyard as the topsides are installed and integrated over the coming years. Since the float, the two accommodation block modules have been installed onto the Prelude FLNG hull. The topside modules are being fabricated and are now progressively being lifted onto the hull.

Some further construction highlights include:

- In Geoje, the 450,000 piping components (a 450km pipe network) are being completed
- The Turret Mooring System (TMS) has been designed by SBM Offshore in Monaco, and is constructed in Dubai Dry Docks. Since August 2014, four turret modules have been shipped from Dubai to Geoje and integrated into the hull
- The mooring chain links, more than 1 metre in length and among the largest in the world, are being produced in Bilbao, Spain at a rate of about 150 links per day. Around 24,500 of these are required for Prelude's 17km of mooring chain.
- FMC Technologies in Malaysia, Norway, France and India are delivering subsea control modules, Christmas Trees, manifolds and wellheads, with two Christmas Trees already installed subsea at the Prelude location.
- The LNG loading arms, designed by Shell and FMC, are manufactured in France and tested cryogenically.
- Kawasaki Heavy Industries is supplying seven boilers which will be used for power generation and LNG production processes
- The Noble Clyde Boudreaux drilling rig was towed to the Prelude field in August 2013, and the campaign to drill the production wells is well underway. Three wells have now been completed.
- In Darwin, in Australia's Northern Territory the Prelude Onshore Supply Base is now complete and receiving equipment and spare parts

Australian Prelude FLNG technicians undergoing FLNG training at the Australian Centre for Energy and Process Training (ACEPT) in Perth, Western Australia..

A piece of the 30 storey turret is installed in the substructure lying alongside the quay.

A 4800 tonne gas processing module is lifted from the quay to be carried around and installed on the Prelude facility.

Building local Operational capacity

As construction progresses, Shell Australia is also building the organisational capability that will be required to operate and maintain Shell's first FLNG development. Shell is drawing on its extensive LNG experience to design and build an operations organisation that can operate FLNG to a world-class-standard.

Recruitment and training of Prelude FLNG technicians has been underway since 2013. As a result, more than 100 Australians are based in Geoje getting to know the technology first hand. Shell Australia has partnered with the Challenger Institute of Technology in Western Australia to develop FLNG training programs for future Prelude FLNG technicians. Challenger will deliver the training, assessment and assurance of process and maintenance technicians so they will be ready to work on the commissioning and start-up of the Prelude facility. Shell has also entered into a partnership with the University of Western Australia and the Energy and Minerals Institute to improve offshore capabilities in Western Australia. The Prelude FLNG project will provide significant benefits to Australia, creating hundreds of jobs and opportunities for Australian businesses, as well as improving Australia's balance of trade and contributing significant tax revenues.

Conclusions

Shell's FLNG technology is leading the way in the development of new ways to help meet growing global energy demands by bringing more natural gas to market.

We are pursuing a design-one-build-many standardisation philosophy so that subsequent developments can be quicker and more cost effective. Through our LNG Programme Team we ensure that all learnings are captured and implemented in subsequent projects.

Shell's leadership in FLNG was further endorsed when Woodside and its co-venturers decided to use Shell's FLNG technology as the development concept for the Browse resources in Western Australia. Shell is providing its delivery capability and technology expertise to support Woodside, as Operator.

Shell has developed an FLNG solution for fields with low liquids content. The 'FLNG Lean' design is a higher capacity FLNG facility that can be applied on fields with lean compositions which do not have the benefit of considerable condensate and LPG revenue streams. By optimizing liquid handling and storage facilities, FLNG Lean is able to achieve LNG production capacities of over 6 mtpa and, depending on the circumstances and characteristic of the field, possibly even more.

FLNG LEAN