Monetising flare gas

Françoise Sabatier and Helmut Steinacker, Linde Engineering Division, Linde AG, Germany, introduce a BOG reliquefaction plant developed for Petronas' LNG complex in Bintulu, Sarawak, Malaysia.

At the end of 2012, Malaysia LNG Sdn Bhd (MLNG), a subsidiary of Malaysian oil and gas company Petronas, placed an engineering, procurement, construction and commissioning (EPCC) contract with Linde Engineering for the world's largest boil-off gas (BOG) reliquefaction plant, adding up to a maximum 0.8 million tpy of LNG capacity to the existing Bintulu LNG complex.

The Petronas LNG complex in Bintulu, Sarawak, comprises three LNG plants owned and operated by Petronas' joint venture (JV) companies. With a total of nine production trains and a combined capacity of more than 24 million tpy, the complex is one of the world's largest LNG production facilities.

Since the first LNG cargo was delivered to Japan in 1983, Petronas has held long-term contracts with customers in mainly Japan, South Korea and Taiwan, supplying a significant share of their domestic natural gas needs.

How flare gases are monetised

The BOG reliquefaction plant helps to improve the overall LNG plant complex efficiency and minimises gas flaring. The target is to reliquefy excessive BOG evaporating out of the LNG storage tanks, which was flared before.

Instead of being flared, BOG is now reliquefied, converted into LNG and routed back to the LNG storage tanks. The project benefits are immense since it will not only increase the LNG production rate and improve plant efficiency, but also significantly minimise greenhouse gas (GHG) emissions.

Innovative concept

Large LNG export terminals include an LNG tank farm with large LNG tanks providing significant storage capacity. Low pressure gases at tank pressure (approximately 100 – 200 mbarg) originate from several sources, such as the following:

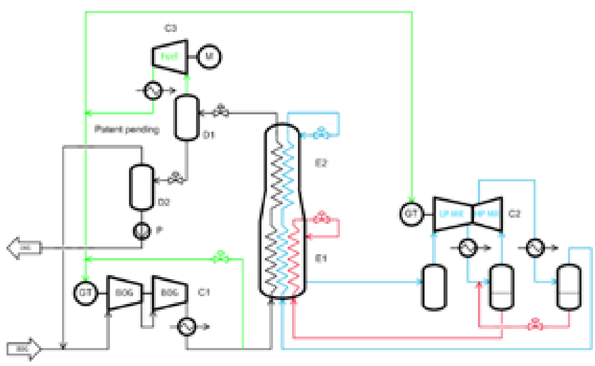

Figure 1. Linde's BOG reliquefaction process.

- BOG caused by heat ingress through the tank walls and LNG pumps.
- Flash gas generated in the run-down line between liquefaction and storage.
- Ship return gas/displacement gas during ship loading.
- Flash gas during cool-down of warm send-out systems.

In total, the overall low pressure gas (hereinafter called BOG) flowrate may accumulate to approximately 1000 tpd for a 10 million tpy LNG facility (this figure can be scaled almost linearly for larger plant capacities). The quality of the BOG may raise concerns as it will be enriched with nitrogen and may contain contaminants from ship return gases. The distance between the liquefaction trains and the LNG storage may add up to a few kilometres depending on the site conditions. Thus, returning the BOG to the liquefaction trains and merging it with the end-flash gas may not be the optimum solution for every site.

Based on the detailed feasibility study and the front end engineering and design (FEED) contract awarded by MLNG to Linde, Linde Engineering and MLNG have developed an innovative concept for a world scale BOG reliquefaction unit with up to 0.8 million tpy capacity, which includes the following features:

- BOG compression starting from cryogenic conditions.
- Mixed refrigerant (MR) cycle with only two heat exchanger bundles.
- Load balancing between feed gas and refrigerant cycle compressors.
- Nitrogen rejection into the gas turbine fuel gas with a double flash process.
- Use of identical gas turbines as mechanical drive.

Technical solution

The BOG reliquefaction unit with a capacity between 0.3 million tpy and 0.8 million tpy of LNG can be compared with mid scale LNG plants. All land-based LNG plants in this capacity range use a single mixed refrigerant (SMR) cycle. This choice is based on its efficiency (typically 350 kWh/t), minimum count of rotating equipment, and good safety records. Considerations to use nitrogen expander cycles for floating LNG (FLNG) concepts are not applicable for a land-based BOG reliquefaction facility, mostly as compact design and readily available make-up supply are not likewise important.

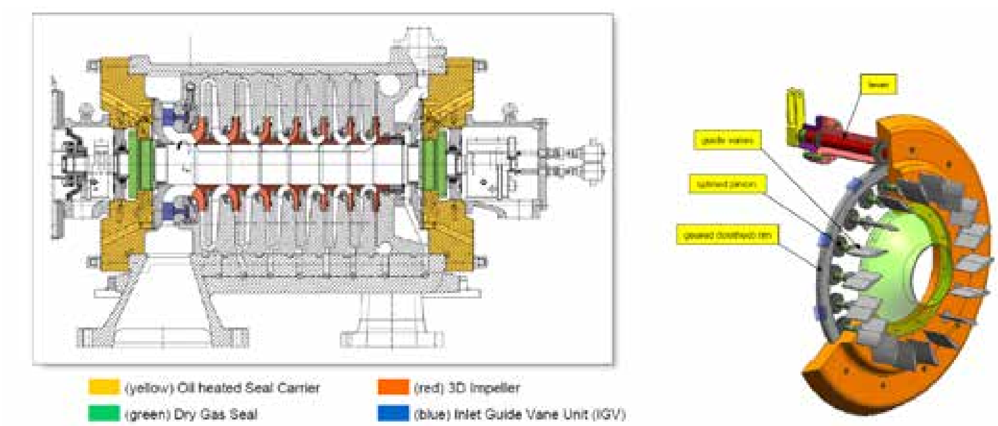

Figure 2. Turbocompressor cross sectional drawing (left) and variable inlet guide vane (IGV) unit (right).

Even if there is some discussion about

the use of brazed aluminium plate-fin heat exchangers (PFHEs) for SMR-based mid scale LNG plants, coil-wound heat exchangers (CWHEs) are often preferred in this service, especially as load changes during ship loading will cause extra stress to the heat exchangers. Evidence suggests that CWHEs are more tolerant to frequent load cycles than PFHEs. The additional cost that comes with CWHEs is offset by the reduced downtime caused by heat exchanger repair.

BOG reliquefaction requires large compression systems for the refrigeration cycle and also for BOG compression, as liquefaction under low pressure would be very inefficient. A typical SMR process with a specific energy consumption of 350 kWh/t requires approximately 15 MW for a feed gas flowrate of 1000 tpd under a pressure of at least 50 bar. Feed gas compression starting from tank pressure to at least 50 bar requires almost the same power. For compressor trains with more than 10 MW each, gas turbines have been selected as the driver in the past, if fuel gas is available under economically attractive conditions. Using electric motors instead of gas turbines seems to be preferable only if and when electric power can be sourced reliably at low prices.

Process arrangement

World scale BOG reliquefaction units have not been built so far. Therefore, a proven process topology has not been available for a cost-effective and robust process design. However, the BOG plant was developed based on Linde's StarLNG™ concept, as well as proven mid scale LNG reference plants.

The chosen SMR cycle is the LIMUM® process, which has been developed and patented by Linde Engineering. It is built around a single-casing, barrel type compressor C2 with two compression stages.

Figure 1 shows the selected design for the BOG reliquefaction system. BOG from the LNG storage tanks has to be compressed first. The low molecular weight of the BOG and the high pressure ratio require two compressor casings for the single shaft, centrifugal compressor C1. In the absence of a need for sour gas removal and dehydration, the compressed BOG is sent directly to the cryogenic heat exchanger, which consists of a precooling bundle E1 and a liquefaction bundle E2. In most of the cases, the nitrogen content of BOG will exceed the standard specification for LNG (under 1 mol%) so that nitrogen rejection is required.

The mixed refrigerant cycle (MRC) compressor C2 is unloaded by shifting part of its duty to the BOG compressor C1. This can be achieved by replacing the subcooling refrigeration duty of the MRC, which was used in E3, by an open methane cycle. Instead of subcooling LNG to such a low temperature that only the desired fuel gas stream is generated, a larger methane-rich flash gas rate is deliberately accepted, which is recycled to the suction side of the BOG compressor C1. Thus, an excellent match between the shaft power of C1 and C2 could be achieved.

Linde's value engineering revealed that instead of conventional nitrogen stripping with a column, a medium pressure flash drum D1 and a low pressure flash drum D2 could be used. The operating pressure of D1 can be selected such that the fuel gas can be compressed in a single-casing, single-stage compressor C3, which can be operated optionally at ambient temperature suction conditions, as the elevated suction pressure allows for a warm-up of the fuel gas before it is compressed.

In total, the value engineering exercise helped to eliminate the subcooling bundle E3 and the low temperature, low pressure casing of the fuel gas compressor C3. The stripper column T was replaced by two simple flash drums D1 and D2.

Load balancing between BOG compressor C1 and LNG MR compressor C2 permits the utilisation of identical mechanical drive gas turbines.

BOG compression system

Among all turbocompressor applications, the cryogenic BOG compressor service is one of the most demanding applications. Due to the nature of the BOG service, the compressor trains are periodically exposed to large fluctuations regarding volume flow and suction temperatures. The proprietary Siemens design features (Figure 2) include a variable inlet guide vane (IGV) control (blue) in front of the impeller (red), protected dry gas seals (green) in a heated and cooled seal carrier (yellow),

Figure 3. BOG reliquefaction plant in Bintulu, Malaysia.

Figure 4. Siemens cycle compressor at BOG reliquefaction plant in Bintulu.

Figure 5. Siemens SGT-700 gas turbine at BOG reliquefaction plant in Bintulu.

Figure 6. BOG reliquefaction plant in Bintulu.

extensive expertise in material selection, compressor design, manufacturing and testing.

The Siemens SGT-700 gas turbine burns natural gas with up to 40% N2 (nitrogen) content, while still minimising atmospheric emissions through the use of a dry low emissions (DLE) combustion system.

Main cryogenic heat exchanger

The heart of the cryogenic section is the CWHE, which is 44 m high, weighs 154 t, and is mounted into a steel structure on site.

Construction and commissioning challenges

In the more than 6 million man-hours invested in the entire construction and start-up phases of the project, there was not a single lost time incident (LTI). However, a number of challenges were encountered throughout the project.

The construction phase proved to be the most challenging project phase. Access was restricted on land by the existing complex infrastructure. As a result, a special jetty had to be purpose-built for the delivery of the CWHE, the gas turbines, the compressors and the flare elements. It was also challenging to work inside the LNG complex alongside operational facilities. Day-to-day production was the top priority and so the plant operators were closely involved in the construction and commissioning phase.

Due to some inopportune circumstances, Linde Engineering had to switch from a modular approach for the air cooler modules to a stick-built system without any preassembly off site.

Coincidentally, the construction of the CWHE structure was optimised by dividing the structure into seven modules that could be assembled more easily on site. Working simultaneously on these multiple modules sped up construction significantly. The situation on the construction site was also exacerbated by the fact that important parts were considerably delayed.

However, with the help of MLNG, Linde managed to control the adverse impact of such construction challenges and was able to move into an effective commissioning phase, where Linde and the client acted as one team. Unfortunately, the start of production was delayed by unexpected problems with a compressor. However, once these problems had been resolved, the team was able to carry out the performance test run to the customer's full satisfaction.

Conclusions

Despite the challenging working environment in an operating LNG plant complex, world scale BOG reliquefaction (and hence the monetisation of flare gas) has become a reality in Bintulu.

Together with MLNG, Linde Engineering has successfully developed and built a new plant type for the LNG industry. Siemens significantly contributed with innovative compressor and gas turbine designs, which are proven in service and are respected worldwide.

MLNG has accompanied this first of its kind project from the very beginning of the concept phase until final acceptance. The client team has supported the design phase of the plant at Linde Engineering's office. On site, an integrated commissioning team of MLNG operation and Linde Engineering personnel has successfully started-up the plant and brought it up to a stable, easy controllable and profitable operation.