The US shale gas revolution has seen net natural gas imports in the US decline since 2007 and, according to the Energy Information Agency’s (EIA) 2015 Annual Energy Outlook, will continue to do so through 2040. Indeed, the EIA goes on to predict that the US, with cheap, abundant gas derived from shale, will become a net exporter of natural gas in 2017.

In preparation for plans to become a major gas exporter – challenging the likes of Qatar and Australia – several LNG export terminals are under construction and more liquefaction facilities are being developed.

One such liquefaction project is an 8 million tpy mid scale LNG facility in the Port of Lake Charles, Louisiana, US, proposed by Magnolia LNG LLC (MLNG) – a newly formed, wholly-owned subsidiary company of Liquefied Natural Gas Ltd (LNG Ltd). The MLNG project serves to liquefy natural gas for export from the US, as well as for potential domestic use. Notably, the facility will use LNG Ltd’s unique, optimised single mixed refrigerant (OSMR®) LNG technology – an innovative, low cost, highly efficient process that uses simple, proven, low risk technology. It will be the company’s first US-based deployment of the technology.

In August 2015, following the signing of an agreement with Meridian LNG Holdings for firm capacity rights for up to 2 million tpy from MLNG, the project took a major step forward, with the subsequent award of a contract to Siemens for the supply of the main refrigeration compression – tailor-made for the process – for the initial two LNG trains.

John Stone and Joel Schubert, Dresser-Rand business within Siemens, USA, look at how efficient compressor technology can help to decrease costs at the Magnolia LNG project in Louisiana, US.
Liquefaction facility
The MLNG project will be situated on an approximately 115 acre site on the Industrial Canal next to the Calcasieu shipping channel, and will be comprised of 4 x 2 million tpy LNG trains and 2 x 16 000 m³ LNG storage tanks. Construction is scheduled to start in 2016, with first LNG production expected in 2018.

The liquefaction process that will be employed at the facility has four main features that contribute to its comparatively high efficiency:

- Efficient gas turbines and compressors.
- Combined heat and power (CHP) plant, which recovers waste heat, thereby minimising plant fuel gas use.
- Steam-driven ammonia refrigeration system.
- Efficient re-liquefaction of boil-off gas (BOG).

LNG Ltd’s OSMR process is based on a simple, single mixed refrigerant cycle, with performance significantly enhanced by the addition of conventional CHP technology and the application of industrial ammonia pre-cooling refrigeration. According to LNG Ltd, the result is a plant cost that is significantly lower than the cost of competing technologies and in a configuration that will be at least 30% more efficient than typical LNG installations, resulting in lower emissions and substantially improved project economics.

Most LNG configurations waste substantial energy by not fully recovering heat from the exhaust of the gas turbine used to drive the refrigeration compressors. As little as one-third of the fuel consumption in traditional LNG plants is converted to useful mechanical energy to drive the compressor. The remainder is wasted to the atmosphere via the exhaust gas turbine.

The OSMR process achieves high thermal efficiency in part by recovering this waste heat in a simple steam cycle, which is then used to satisfy all process heat and ammonia refrigeration energy requirements for the complete plant.

Process description
Following pre-treatment of the feed gas to remove acid gas, heavy hydrocarbons and water, sweet dry gas is pre-cooled by ammonia and then enters the cold box, where it is liquefied at high pressure against the mixed refrigerant. The produced LNG exits the cold box and flows to the LNG tank, where it flashes to low pressure. The flashed vapour BOG is recovered from the LNG tank by high-efficiency BOG compressors. One compressor per train operates during normal operation, while an additional unit is started during ship loading.

Refrigeration for the cold box is principally provided by the single mixed refrigerant supplemented by ammonia refrigeration at the warm end (top) of the cold box. The ammonia refrigeration plant is powered by ‘free waste energy’ that is generated by the CHP plant.

The sizing of the ammonia refrigeration plant is largely based on the spare power available from the CHP plant after all other heat uses within the plant have been met. This ensures optimum use and balance of all available energy.

The ammonia refrigerant is first applied to cooling wet gas from the amine contactor to condense out water. Secondly, it is applied to cooling inlet air to the gas turbines to increase power. The remainder is used in the cold box for pre-cooling the mixed refrigerant and to pre-cool the feed gas. The result is a substantial increase in plant capacity and a substantial improvement in fuel efficiency. As an added bonus, pure water is condensed and produced when gas turbine inlet air is cooled with ammonia, thus minimising the make-up water to the plant.

Ammonia refrigeration uses a conventional industrial refrigeration process that uses steam turbine-driven compressors.

The single mixed refrigerant cycle consists of a suction scrubber, compressor, after-cooler, ammonia pre-cooling and cold box. It uses a standard single process-stage centrifugal compressor.

Figure 1. Siemens’ SGT-750 industrial gas turbine.

Figure 2. Siemens’ SGT-750 industrial gas turbine design is a growth extension of the company’s SGT-600 – SGT-700 family of industrial gas turbines.
LNG trains

Siemens’ scope of supply to the facility comprises a total of eight refrigeration compressors and two feed gas booster compressors for the initial two LNG trains. This scope will then be expanded into the full four train facility.

Four mixed refrigerant Siemens STC-SV barrel-type compressors, with horizontal split casing, will each be driven by a Siemens SGT-750 industrial gas turbine, while four ammonia refrigerant STC-SV compressors will each be driven by a Siemens SST-600 steam turbine. Additionally, the initial scope of supply includes two motor-driven feed gas booster compressors (one per train). The subsequent two LNG trains necessary to achieve the full 8 million tpy for the MLNG project will bring the total number of compressors at the site to 20.

The SGT-750 industrial gas turbine driving the mixed refrigerant compressors was one of the primary reasons for selecting Siemens for the project, because the turbine’s power rating is a good match for the LNG train design. Its power output is more than enough for the project’s requirements. The SGT-750 also has low emissions and low operating expenditures over the plant’s lifetime.

Turbine design

The SGT-750 industrial gas turbine design is a growth extension of the company’s SGT-600 – SGT-700 family of industrial gas turbines. These turbines are designed to meet the demands of both the industrial power generation and oil and gas markets, utilising robust designs that feature tilting pad journal bearings and a mineral oil lubrication system.

The turbine was first introduced in November 2010 as part of Siemens’ industrial gas turbine range (5 – 50 MW). The first unit went online at the CHP plant in Lubmin, near Greifswald, Germany.

In addition to being a multi-purpose turbine for the power generation sector, the new turbine is also well suited to mechanical drive applications in the oil and gas sector. The gas turbine has been specifically designed for long operating hours, with extended maintenance intervals to reduce downtime.

Delivered as a package, with a footprint of 12.8 x 4.3 m, the turbine is designed with service in mind, offering easy access to all of the key components. It is assembled as a unit on a single-lift frame, with a divider between the turbine and the driven equipment.

With high reliability a key goal, Siemens looked at how packages were designed in its existing industrial gas turbines, as well as at certain design aspects of its large heavy-duty machines. Solutions from its own gas turbines, as well as from competing machines, were incorporated into the SGT-750 turbine package.

The turbine is a two-shaft machine optimised for simple cycle. It has a single, rigid rotor compressor body that is electron beam-welded to ensure reliable, stable and uniform run-up in hot or cold conditions. Axial blade attachment grooves allow blade replacement, without rotor removal.

The machine features a 13-stage axial flow compressor, with a pressure ratio of 23.8:1. Two variable guide vanes in the compressor offer optimised performance, even in the most extreme conditions.

To make servicing easier, the compressor turbine is bolted to the compressor, so that it can be easily exchanged as a module.

In the power turbine, it is important to be able to optimise the settings for each individual installation. The turbine must be able to generate the maximum amount of power, regardless of ambient conditions, and, therefore, uses a free power turbine.

This is a two stage, high speed module nominally running at 6100 rpm that is equally suited to mechanical drive applications, or, with a speed reduction gear, power generation.

One further development for this size of gas turbine was the inclusion of infrared camera access ports to monitor the first – and second – row turbine blades during operation and inspection. The cameras are able to detect the slightest change in temperature to allow technicians to carry out the right actions at the right time in the event of an irregularity.

Using a temperature sensitive camera allows the temperature pattern of each blade to be measured. This technology, developed in Orlando, Florida, US, is widely used in large gas turbines. It allows engineers to know what they will find before opening a machine. This helps to ensure that service activities are prepared in advance, so that maintenance times can be kept to a minimum.

In the future, it is hoped that the use of cameras will help operators to extend the life of the turbines and be more flexible on service intervals. For example, if an...
operator wants to run for additional time outside of the maintenance interval, data from the cameras will assist in making fact-based decisions.

State-of-the-art serviceability and maintenance was a major consideration during the development of the SGT-750 turbine.

The maintenance concept is aimed at achieving the lowest lifecycle cost. Time between major overhauls is designed for 68,000 equivalent operating hours, or approximately 8 years. It is also possible to achieve four years of operation before the machine needs to be opened.

At the launch of the turbine, one of the key slogans was ‘17 days in 17 years’ – a reference to what is possible in terms of downtime of the machine.

The SGT-750 turbine, with its twin shaft configuration, is designed for both power generation and mechanical drive, driving compressor or pumps, either onshore or offshore. The free power turbine enables the gas turbine to start with a minimum of power, even when connected to fully pressurised compressor loops.

In terms of fuel flexibility, the turbine is a dual-fuel machine that is capable of running on natural gas and light distillate oil. The combustion system is able to handle a wide fuel specification for natural gas. This could include gas, with a high nitrogen content, from depleted wells, refinery gases or hydrogen-rich gases, for example.

The combustion system uses the fourth generation Siemens dry low emission (DLE) burners to control NO\textsubscript{x} emissions to single digit levels and allow a wide turndown ratio. The machine can achieve a turndown ratio of 50%, while still maintaining NO\textsubscript{x} emissions of 15 ppm. In markets where NO\textsubscript{x} limits are not as strict, it is possible to turndown to as low as 30%.

**Managing the compression chain**

Apart from the performance of the gas turbine, an important factor in Dresser-Rand (part of Siemens) successfully securing the contract was its ability to provide the entire compression train. This enabled MLNG to bundle the full compression train through a single supplier for better support, reliability and project efficiency. This approach simplifies mechanical design, reduces interfaces for better project management, streamlines commissioning, and generally reduces overall project risks.

Siemens’ compression trains and associated equipment will be assembled as modules and shipped to the project’s module fabrication yard. This will reduce the manpower needed for assembly on site, which is important in an area where there is concern that there may be insufficient labour and laydown area to effectively handle the LNG facilities being constructed.

Construction of the LNG trains at the MLNG project is expected to begin in early 2016, with the first compressors to be delivered to the module fabrication yard in early 2017. The MLNG project will be an important demonstration of the turbine’s effectiveness in such applications, especially for mid scale LNG facilities.

**Reference**