COMPRESSION 'Down Under'

Brian Mason and Chirag Sehgal, Siemens Energy, discuss how Australia is preparing for the hydrogen economy by way of retrofitting existing compression and transportation infrastructure.

The success of the energy transition hinges on creating sustainable, reliable and affordable energy supply for all. Achieving this will require a diverse and balanced energy ecosystem with contributions from both natural gas and renewables. Hydrogen will also play a critical role in opening up new decarbonisation pathways, particularly for industries that have been deemed hard-to-abate.

As the world's largest exporter of LNG, and a hub for renewable energy, Australia is in a good position to become a global leader in the clean hydrogen market. In 2021, 29% of the country's total electricity generation was from renewable energy sources, including solar (12%), wind (10%) and hydropower (6%).[1] More than 80 GWe of green hydrogen production projects have already been announced in the country.[2] Initiatives to increase blue hydrogen capacity via coal regasification and steam methane reforming of natural gas, in combination with carbon capture, are also gaining traction.

While continued production growth will be key to establishing a robust hydrogen economy in Australia, a reliable and efficient transport network is also needed to enable widespread domestic use, and for exporting hydrogen to demand centres in Asia-Pacific and other regions of the globe.

Among all modes of transport, pipelines remain the most efficient option for moving large volumes of hydrogen. Several thousand kilometres of pure hydrogen pipelines are in operation across the globe today. Given the high cost and regulatory hurdles associated with building these pipelines, many stakeholders across both public and private industry have begun asking whether it is possible to use existing natural gas infrastructure to move hydrogen.

This article will provide answers to these questions by discussing what (if any) modifications are required to prepare legacy compression stations for partial or even 100% hydrogen operation.

Transporting hydrogen vs natural gas

Although the calorific value (CV) of natural gas is roughly three times higher than that of hydrogen, the energy transport density of identical pipelines carrying the two would be relatively similar. This is largely due to the much lower density of hydrogen, which allows for higher velocity and flow rates. In long-distance transmission lines, which typically operate at high pressures, energy flow with high contents of hydrogen hardly decreases in comparison to pure natural gas operation.

While blending hydrogen with natural gas does not materially affect the amount of energy that can be transported through the pipeline, it does have implications when it comes to compressibility – particularly when using centrifugal (i.e. turbo) compressors, which utilise high-speed impellers to convert rotational/kinetic energy into pressure.

The gas kinetic energy is a direct function of its velocity and molecular weight. Hydrogen's molecular weight is roughly 1/8th of that of natural gas, which means a higher velocity is required to achieve the same pressure. This can be done in one of two ways. The first is by increasing impeller tip speed and/or expanding the diameter of the impeller. The limiting factor here is the mechanical strength limits of the impeller materials. The second is by incorporating additional compressor stages, which increases the overall footprint and cost of the package.

Significant advancements by original equipment manufacturers (OEMs) have been made in recent years, which have enabled turbocompressors to better handle hydrogen. Siemens Energy's STC-SVm platform, for example, is specifically designed for high rotational speeds and allows for a smaller and lighter compressor unit with fewer stages than legacy machines in hydrogen service.

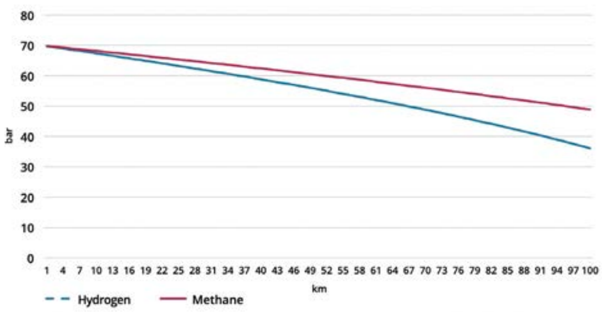

Figure 1. Pressure curve when transporting methane and hydrogen with the same energy content in a 100 km long high-pressure pipeline with a diameter of 1000 mm.

Figure 2. Siemens Energy's STC-SVm turbocompressor platform.

Many existing turbocompressors in pipeline applications today can be operated with a low content of hydrogen in the gas stream. However, as the percentage of hydrogen by volume increases, modifications to the machine are necessary to ensure safe and efficient operation.

Typically, for admixtures with less than 10% hydrogen by volume, no major changes to compressor hardware are required. The compressor housing can often be maintained, with up to 40% hydrogen content. However, modifications/adjustments to impellers, feedback stages, and gears are likely needed. For pipelines with greater than 40% hydrogen content, replacement of the compressor is the most practical solution.[3]

Reciprocating compressors

Unlike turbocompressors, reciprocating compressors work on the principle of positive displacement. As a result, the low molecular weight of hydrogen does not compromise compression efficiency. This typically makes them a more practical option for hydrogen service in many applications, including pipelines and electrolysis plants, which often operate at partial loads. Siemens Energy currently has more than 2 million hp of reciprocating compression installed in hydrogen-rich services, including tail gas, feed gas, and make-up services, as well as pipeline and storage.

Achieving a pressure ratio of 4:1 in a pure hydrogen application can typically be accomplished with a reciprocating compressor in just two stages. In pipelines, transport capacities of as high as 750 000 Nm^3/hr can be achieved by increasing drive power and operating units in parallel.[4]

Hydrogen's smaller molecular size relative to natural gas does mean that certain modifications to seals may be required to minimise internal and external leakages. Other design areas that require attention include compressor valves, lubrication, and capacity control. In many cases, these modifications can be made without replacing the entire compressor.

New compressor installs

For new hydrogen compression applications, the optimal compressor choice will ultimately be dictated by several variables, including the facility's footprint, CAPEX, OPEX, availability/reliability, turndown requirements, etc.

Both reciprocating and turbocompressors can handle a broad range of operating scenarios, with the choice of technology based on economic trade-offs and the specific requirements of the pipeline, including required flow rates, pressure ratios, use of dry or wet sealing, and the percentage of hydrogen in the admixture.

While the specific production method (e.g. electrolysis, steam methane or auto-thermal reforming, coal regasification, etc.) is irrelevant – as compressors do not see 'colour' – there are several key characteristics of the hydrogen that must be considered, such as gas composition, water content, wet vs dry flow, suction pressure, gas temperature, lube-oil carryover, etc.[5]

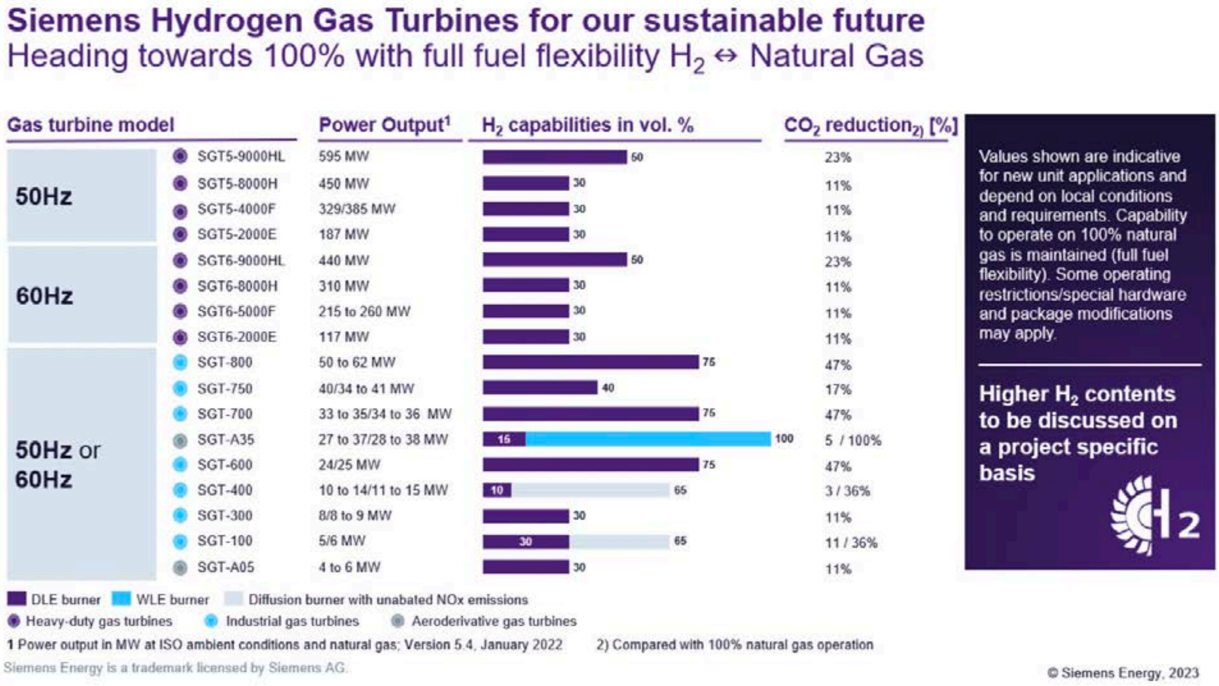

Figure 3. Hydrogen-burning capabilities across Siemens Energy's gas turbine portfolio.

For end users, failure to specify these values to OEMs early in the design process can result in a number of undesirable outcomes, including higher costs, reduced performance, and higher power consumption.

Compressor drivers

Blending hydrogen with natural gas will also necessitate modifications to compressor drivers (in some cases). Many compression stations across Australia are in highly-remote regions and thus rely on burning pipeline gas for drive power. Turbocompressor trains typically use gas turbines as mechanical drives or occasionally to drive generators for onsite electricity production.

Under adiabatic and stoichiometric conditions, the flame temperature of hydrogen is more than 300˚C higher than natural gas. Laminar flow speed is also higher for certain flame temperatures. This introduces unique challenges when it comes to combustion system dynamics and subsequently achieving acceptable emissions levels from the turbine.

In recent years, OEMs have made a great deal of progress in adapting gas turbines for hydrogen. Siemens Energy, for example, currently has more than 55 hydrogen gas turbines installed around the world, which have amassed > 2.5 million hours of operating experience. The company has established an ambitious goal of making all turbine models 100% compatible with hydrogen by 2030.

Today, units of varying sizes and combustion system types (e.g. unabated diffusion flame, wet low emissions [WLE], dry low emissions [DLE]) can reliably handle fuel admixtures with high contents of hydrogen. As is the case with compressors, the decision to modify an existing gas turbine or replace it will depend on several factors, including the hydrogen content in the admixture, the age of the unit, required drive power, objectives of the operator, etc.

Looking ahead

In the coming years, as production of green hydrogen in Australia increases, so too will the need for dedicated pipelines that can efficiently transport hydrogen from electrolysis plants to processing facilities (e.g. e-ammonia or e-methanol plants) and export terminals. Much of the demand in the near-term will be for short-distance, pure hydrogen lines. However, establishing a robust hydrogen economy over the coming decades will necessitate leveraging the country's 39 000+ km of existing natural gas infrastructure.

While further research and development work on the part of OEMs will be required in order to optimise equipment for hydrogen, the challenges of hydrogen transport can largely be addressed using today's technology. The key moving forward will be to establish a clear regulatory framework so that operators can plan and make investments accordingly.

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