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Hybrid compressor drive for LNG plant



Hybrid compressor drive for LNG plant vs. all-electric or all-mechanical design

By Joel Schubert, Siemens Energy and Boris Brevnov, Northeast Energy Center

LNG production plant features a first-of-its-kind hybrid drive (gas turbine, electric motor/generator and integrally-geared compressor) refrigeration unit for optimized performance, flexibility, and economics – while minimizing environmental impact

Near the intersection of the interstate Tennessee Gas Pipeline, a high-voltage electric transmission corridor and the interstate highway in south central Massachusetts, a new Northeast Energy Center (NEC) LNG project is almost completed and getting ready for plant start-up.

The project considered of strategic importance to the energy security of New England features one of the few utility-scale natural gas liquefaction facilities under development in the United States whose LNG is not intended for export – and, in fact, replacing import.

At the heart of the LNG plant is a hybrid (gas-electric) integrally geared nitrogen refrigeration compression train supplied by Siemens Energy, first of its kind in the world, which will uniquely enable:

- Supplementing on-site gas turbine with grid or micro-grid power to meet both refrigeration compression and onsite electricity needs
- Optimal selection of gas turbine size to minimize cost and environmental impact
- Reduction in fuel consumption and associated emissions at site
- Transforming plant into net power exporter to local grid during seasonal periods when full LNG capacity is not required or electric power is in high demand

Gas turbine vs. electric drives

For many assets along the natural gas supply chain (e.g., LNG plants, gas processing facilities, compressor stations, etc.) generating the horsepower required to drive refrigeration compression trains represents a large portion of facility emissions and operating expense (OPEX).

Gas turbine mechanical drives still serve as a reliable and efficient solution. However, tightening federal and state regulations, rising public and community expectations, and voluntary environmental and social commitments by responsible energy providers make electrification increasingly attractive.

Electric motor drives offer several advantages over gas turbines such as lower maintenance costs, higher efficiency, and increased turndown capabilities. But risks that come with a con-

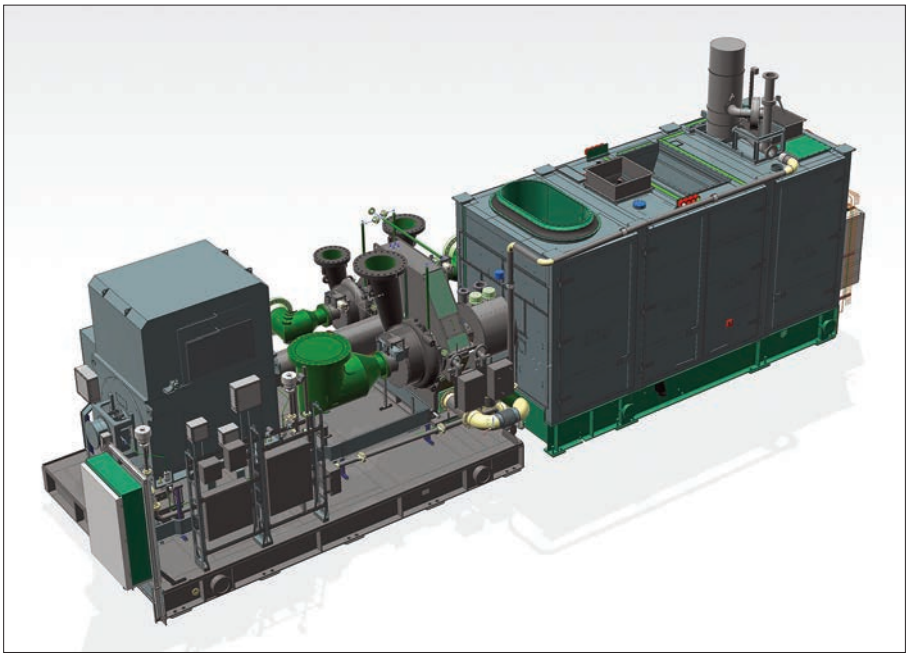


Figure 1. NEC hybrid drive refrigeration compressor train package. The assembled refrigeration train comprises an integrally geared type compressor (center) and 8MW dry low emissions (DLE) SGT-300 gas turbine (on the right) with a 4MW motor/generator (left) mounted on the same base plate as the compressor.

nection to the external grid, including reliability and voltage instability, can affect plant availability.

For places close to major load centers, the cost of electricity may often be more expensive than gas. In addition, spikes in grid-power prices, demand charges, and congestion fees are also a concern.

Hybrids combine best of both

A hybrid or dual drive combines two or more mechanical drive components such as a steam or gas turbine with an electric motor (or motor/generator) into a single train.

This protects operators against being locked into a single energy source by giving them the flexibility to use natural gas, grid electricity, or a combination of the two to meet onsite energy demands. Several configurations are possible depending on the application and specific type of equipment being used.

In the case of the NEC facility, which utilizes an STC-GV integrally geared nitrogen refrigeration compressor, a motor/generator is fixed to one end of the compressor shaft and an 8-MW dry-low emissions (DLE) SGT-300 industrial gas turbine is coupled to the other. Siemens Energy is supplying all components for the packaged train unit.



Figure 2. Compressor and motor drive skid. The Siemens Energy integrally geared compressor package (left) and 4MW motor/generator unit (right) mounted on the same base plate being prepared for shipment to NEC plant site.

An artist rendition of the equipment package for this integrally geared hybrid refrigeration train is shown in Figure 1. In this configuration the com-

Table 1. Hybrid drive train performance.
Data for hybrid N_2 refrigeration compressor drive train operating at nominal 250,000 gallons per day (GPD) LNG production rate showing power split between gas turbine and motor/generator drives. Note fall-off in LNG production (bottom line) with increasing ambient temperature, without supplemental motor to fill shortfall in compressor power.

Ambient Air Temperature	**30 deg F**	**60 deg F**	**90 deg F**	**95 deg F**
Compression Train				
Nitrogen mass flow	410,958 lb/hr	410,958 lb/hr	410,958 lb/hr	410,958 lb/hr
Inlet pressure	115.5 psia	115.5 psia	115.5 psia	115.5 psia
Inlet temperature	76.1°F	76.1°F	76.1°F	76.1°F
Discharge pressure	475.5 psia	475.5 psia	475.5 psia	475.5 psia
Compressor power	11,421 hp	11,421 hp	11,421 hp	11,421 hp
Gas Turbine & Motor				
Gas turbine power output	12,037 hp	10,701 hp	9,264 hp	8,986 hp
Gas turbine efficiency (LHV)	36.0%	34,8%	33.0%	32.6%
Electric motor operating mode	Generator	Motor drive	Motor drive	Motor drive
Motor power (generator power)	(616) hp (460) kW	720 hp 537 kW	2,158 hp 1,610 kW	2,435 hp 1,817 kW
Percent power supplied by motor drive	n/a	6%	19%	21%
LNG production rate w/o motor drive	263,484 GPD	234,240 GPD	202,762 GPD	196,699 GPD



Figure 3. Gas turbine drive skid. The fully enclosed Siemens Energy 8MW SGT-300 gas turbine package mounted on its own base plate will be mated with the compressor/motor skid in the field.



Figure 4. SGT-300 gas turbine delivery at NEC site. The gas turbine and compressor/motor skids will be housed within the turbine compressor building under construction at the site.

pressor is pinion-driven from the gas turbine side and bull gear-driven from the motor/generator side with no need for clutches or a separate gearbox.

Figures 2 and 3 show individual equipment skids prepared at the Siemens Energy Houston plant for shipment and installation at the NEC site. A single skid-mounted lube oil system will supply conditioned oil for the entire train.

For trains that use single-shaft centrifugal (i.e., turbo) compressors, a typical configuration could comprise a gas turbine with a clutch on one side and an electric motor with a speed-increasing gearbox, and a clutch on the other side.

Switching between the motor and the gas turbine is possible via engagement and disengagement of clutches, with minimal disruption to train operation.

With hybrid drives, the electric motor could be the primary driver when low-cost electricity is available from the grid – with the gas turbine serving as back-up or as a power booster as with the NEC project.

In this way a smaller, optimally sized gas turbine can be selected to operate fully loaded at maximum efficiency. The motor or motor/generator supplies any additional horsepower required for compression duty, a feature especially important at higher ambient temperatures when gas turbine power falls off.

During colder periods, when the gas turbine might produce more horsepower than required, the motor/generator (acting as a generator) can produce electricity which may be used on site or sold to the grid.

By always running the gas turbine at an optimal load, NOx and CO emissions are reduced, as are fuel consumption and associated CO_2 emissions.

Hybrid drives for process plants

Siemens Energy has installed several hybrid drive trains in refinery applications, specifically in exothermic (heat releasing) Purified Terephthalic Acid (PTA) process units. There, the equip-

ment train includes a steam turbine driver, integrally geared compressor, motor/generator, and a hot gas expander.

The motor/generator is initially used as a motor to drive the train to supply compressed air needed to start the process. Once operating, the process produces steam and hot off-gas to power the steam turbine and hot gas expander which drive the motor/generator, now acting as a generator.

Typically, this hybrid arrangement generates more electric power than can be used at the site and any excess can be exported to the local power grid.

Hybrid drive configurations with larger gas turbines have also been used in the chemical sector where the production process allows use of gas turbines as an alternative to steam turbines for driving compressors.

In South America, for example, Siemens Energy installed a train comprising an SGT-600 gas turbine (~25MW) with an STC-GV integrally geared compressor and motor/generator. Electric power generated by the train will be used directly for fertilizer production, reducing the power purchased from the grid.

NEC project overview

The NEC project is positioned in south central Massachusetts near the Tennessee Gas Pipeline interstate pipeline system. Plant scope includes a natural gas liquefaction facility, LNG field erected storage and truck loading bays, a gas interconnection pipeline, and a gas meter station.

ZAP Engineering & Construction Services as EPC contractor on the project is responsible for design and construction of the LNG facility. The liquefaction process equipment, supplied by Chart Energy & Chemicals, includes a pretreatment unit to remove impurities from incoming natural gas and a nitrogen liquefaction refrigeration unit that will process treated natural gas to produce LNG.

Northeast Energy Center LNG Project

NEC's new facility in south central Massachusetts is one of the few utility-scale natural gas liquefaction plants under development in the United States whose LNG is not intended for export.

It will produce a baseload of 170,000 gallons per day of LNG for Boston Gas under firm contract plus up to another 80,000 GPD for sale to other utilities and industrial power generation customers.

It also will be the first in the world to use a ***hybrid*** LNG refrigeration compressor train powered by a relatively small gas turbine combined with an electric motor/generator. The combination will enable the hybrid system to meet power requirements and operate efficiently regardless of seasonal ambient air temperature changes.

Adding an electric motor drive to the refrigeration train allowed NEC to "undersize" the gas turbine so it would operate year-round at or near its most efficient full-load design point.

A traditional mechanical drive without a supplemental motor drive would require a larger gas turbine to ensure sufficient horsepower to meet compression requirements during the summer when higher air temperatures result in reduced power output.

During winter, with low ambient temperatures and higher power output, the larger gas turbine would have to be operated at partial load, reducing efficiency and increasing emissions.

With the NEC hybrid system, any excess power generated by the gas turbine at full load could produce electricity for export to the local grid as the motor would be operated as a generator.

For the NEC plant with the hybrid drive, gas turbine fuel consumption decreases by 16% and associated CO_2 site emissions decrease by 14% – as written into the air permits.

The self-contained cold box in the Chart system encompasses the primary cryogenic equipment including a brazed aluminum plate-fin heat exchanger and knock-out drum for removal of heavier components of the natural gas feed, piping, valves and instrumentation (Figure 5).

Prioritizing costs and emissions

NEC's decision to install a hybrid drive for the main nitrogen refrigeration train was based on several factors – the most important being to minimize costs and overall environmental impact.

A traditional mechanically driven refrigeration train without a motor would have resulted in the need for a larger gas turbine to ensure sufficient horsepower is available to meet compression requirements during all operational scenarios and seasonal ambient and pipeline conditions.

Since gas turbine power output decreases with increases in ambient temperature, matching equipment size and power requirements is a critical issue in regions such as New England to cope with significant seasonal temperature fluctuations.

(Note: as a rule of thumb approximation, gas turbine power output changes

inversely by about 0.5% for each 1°F change in ambient air temperature.)

Operators commonly specify an "oversized" gas turbine to ensure enough power can be generated during times of high ambient temperatures. This adds to the plant CAPEX, also means that during cold months the turbine must be operated sub-optimally at partial load, thus reducing fuel efficiency and increasing emissions.

Adding a motor/generator to the train allows NEC to operate the smaller optimally sized gas turbine year-round at or near its most efficient full-load design point. During hot summer months, when gas turbine cannot meet compressor demand, the grid-connected motor provides supplemental power to bridge the gap.

By running the smaller gas turbine in a more efficient operating range (70-100% load), NOx and CO emissions are reduced by 40% and 10%, respectively (to single-digit levels) versus running a larger gas turbine at reduced load.

In addition, fuel consumption and associated CO_2 emissions decrease by 16% and 14%, respectively. Based on employing the hybrid drive configuration, these emission reductions were written into the air permit for the project.

For the future, NEC is exploring the potential use of hydrogen-blended fuel to further reduce emissions and help meet decarbonization goals. The SGT-300 industrial gas turbine with Dry Low Emissions (DLE) burners can burn up to 30% (vol) of hydrogen blended with natural gas.

The SGT-300 can also operate on gas fuels outside of standard pipeline quality over a Wobbe fuel range from approximately 50 MJ/m³ down to 17.5 MJ/m³) – including minimally processed weak biogas from ethanol, industrial waste gas, or landfill gas.

Dual purpose motor/generator

As described, the drive motor can act dually as a generator when the gas turbine produces more horsepower than required for compression. At the NEC plant up to 4MW of electrical power can be generated for site duty or for export to the grid.

This is strategically important for NEC since electricity prices in New England are among the highest in the country. The ability to self-generate power at a cost roughly one-quarter the electric grid price will result in substantial cost savings while reducing the risk of plant downtime associated with grid disruptions.

Table 1 contains data representing the 250,000 GPD maximum production design condition of the hybrid train. It shows the split between the gas turbine and motor/generator in meeting total compressor power requirement of 11,421 hp over a 30°F to 95°F range of ambient temperature.

At 30°F, where gas turbine output exceeds this requirement, the surplus is shown as negative motor power (positive generator output power). Note that at 95°F the motor/generator provides over 20 percent of the compressor power requirement for full production. Without the motor to provide this supplemental power the LNG production rate would fall off to about 197,000 GPD.

If the economics are favorable, NEC can export/sell self-generated surplus power back to the utility. This allows the plant not only to participate in demand-side management but also serve as a distributed generator.

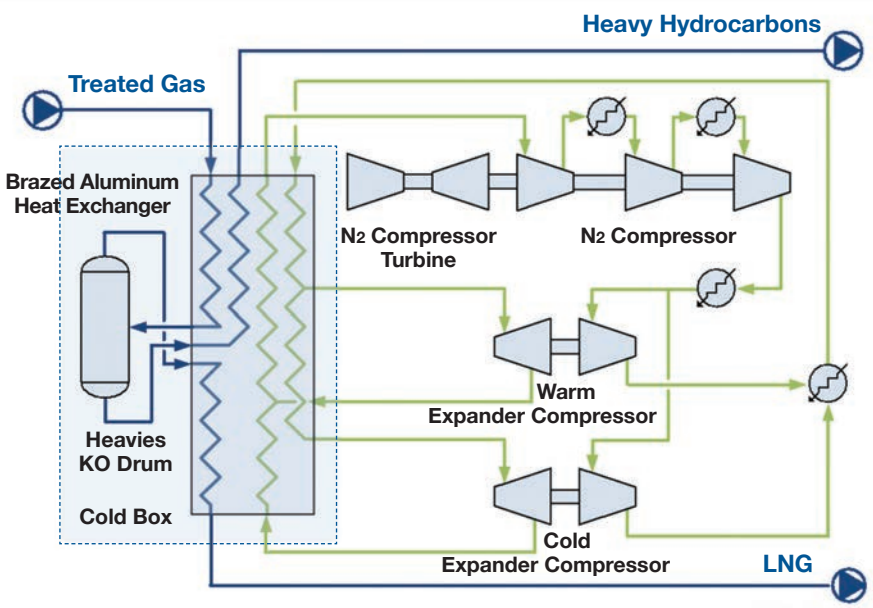
The case for hybridization

The gas-electric drive installed at the NEC facility represents a highly flexible solution that will enable the liquefaction plant to operate at maximum efficiency year-round, regardless of ambient temperature and pipeline gas pressure conditions.

This will reduce energy consumption over the project's life and contribute to NEC's decarbonization goals while reducing impacts on the surrounding community.

The project has been a highly collabo-

Figure 5. Refrigeration cycle for LNG production. Simplified process diagram for nitrogen refrigeration cycle and cryogenic unit to cool and liquefy treated natural gas. The self-contained coldbox features a brazed aluminum heat exchanger (BAHX) to handle the cryogenic duties. (Courtesy: Chart Energy & Chemicals)



rative effort that involved close coordination between all project stakeholders, including NEC, Siemens Energy, ZAP Engineering & Construction, and Chart Energy & Chemicals.

While it marks the first hybrid drive integrally geared compression train to be installed in the U.S., Siemens Energy has implemented similar configurations at several industrial facilities across the globe.

Ultimately, site-specific variables and operator objectives will dictate the decision to utilize a hybrid drive. However, evolving environmental regulations and permitting complexities in many regions of the world makes it a desirable option for meeting compression duties, particularly in pipeline stations, LNG plants, and gas processing facilities. ■

The authors: Joel Schubert is Director of Business Development, LNG at Siemens Energy and Boris Brevnov, is Manager/Developer Northeast Energy Center LLC



Figure 6. NEC project layout. Northeast Energy Center facility to include LNG production and storage, gas interconnection pipeline, gas meter station and truck loading bays. (Courtesy ZAP Engineering & Construction)