CONVERTING DOMINION COVE POINT LNG INTO BIDIRECTIONAL FACILITY

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ABSTRACT

Dominion Cove Point LNG, LLP is integrating a single natural gas liquefaction train of 5.25 MTPA production capacity into its existing import facility, which has send out capacity of 18.7 Bcm/y and 690,000 m^3 of LNG storage capacity.

The Cove Point LNG facility is located in Maryland (USA). Innovative design features are necessary to meet stringent local, state, and federal environmental and regulatory requirements. The design addresses these challenges by using new technologies and process features, many of which have not previously been implemented in the LNG industry.

Key features of the new facilities are: a feed gas recycling system to minimize the potential for flaring during start–up; all refrigerant compressor services included on each of two identical parallel strings; a new main cryogenic heat exchanger cool down procedure; a highly efficient islanded power generation system that uses exhaust heat from the gas turbine compressor drivers, and zero liquid discharge processing facilities.

These unique design features also provide needed flexibility for facility operations, all within the confines of the existing terminal, which will remain in service as an import facility throughout the liquefaction integration.

The challenges associated with implementing the new technical concepts were met through close cooperation among all involved parties; including the design and project management team, LNG import operations team, facility owner, technology licensor, and major equipment suppliers.

INTRODUCTION

The existing Dominion Cove Point LNG import terminal was commissioned in 1978 with a sendout capacity of 10.4 Bcm/y and LNG storage volume of 238,000 m^3. Additional sendout capacity and storage were added in several stages to bring the current capacity to 18.7 Bcm/y and LNG storage to 690,000 m^3, with the latest expansion occurring in 2008.

In September 2011, Dominion began the lengthy application processes seeking to export LNG first to countries that have Free Trade Agreements (FTA) with the United States and then to non-FTA countries.

In June of 2012, Dominion submitted a request to initiate the pre-filing process with the Federal Energy Regulatory Commission (FERC) for a liquefaction project at Cove Point.

In September 2013, approval was received from the U.S. Department of Energy for natural gas exports to non-FTA countries.

In April 2013, Dominion filed an application with the FERC, seeking authorization for the Cove Point liquefaction project and also contracted with IHI/Kiewit for engineering and construction services.

FERC approved the application in September 2014. Construction activities began at the facility in October 2014.

IHI/Kiewit Cove Point, a joint venture between IHI E&C International Corporation of Houston, Texas and Kiewit Corporation of Omaha, Nebraska, is the engineering, procurement, and construction contractor for the new liquefaction facilities. The liquefaction technology used is the Air Products AP-C3MR™ process. Refrigeration compressors and gas turbine drivers are provided by GE Oil & Gas.

PROCESS OVERVIEW and HIGHLIGHTS

The basic plant process flow scheme is depicted in Figure 1. Explanations of key design concepts follow.

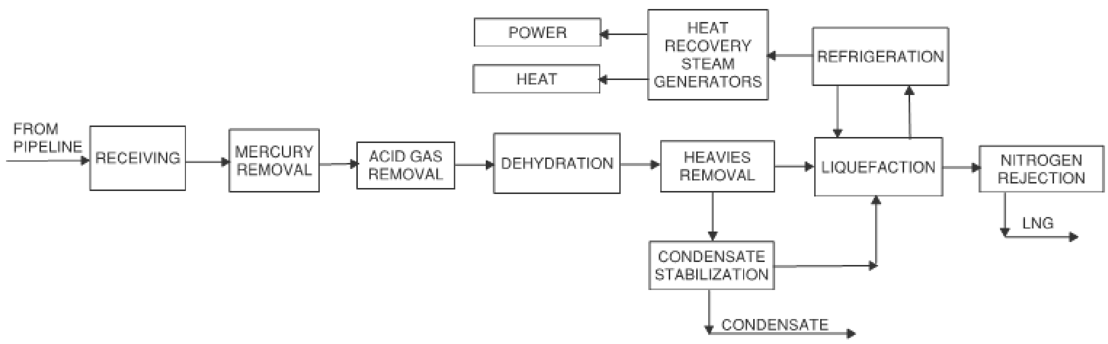

FIGURE 1. PROCESS FLOW SCHEME

Mercury Removal. The Mercury Removal Unit is located directly downstream of feed gas receiving, thus preventing mercury from entering any of the downstream units.

Acid Gas Removal. Acid gases are removed using a diglycol amine (DGA) solution. Due to engineering constraints the unit contains two parallel absorbers instead of one larger absorber. The unit includes an amine reclaimer to remove heat-stable salts and other heavy contaminants.

An antioxidant is injected into the DGA solution to negate the effects of up to 200 ppmv oxygen that may be present in the feed gas. Hydrogen sulfide in the acid gas leaving the amine regenerator is removed by scavenging upstream of a thermal oxidizer, minimizing both H_2S and SO_x emissions.

Gas Dehydration. Gas dehydration uses molecular sieves with a unique closed loop regeneration system to enable processing of feed gas with as much as 200 ppmv oxygen. Normally a slip stream of dried feed gas is used for dryer bed regeneration. However, oxygen in the regeneration gas could react with adsorbed heavy hydrocarbons and foul the sieve. For Cove Point the closed regeneration loop reduces oxygen in the regeneration gas to prevent this fouling.

The closed loop includes a separate regeneration gas dryer and a regeneration gas compressor. Oxygen in the closed loop combusts some regeneration gas after it is heated in the regeneration gas heater to produce water and CO_2. The bulk water removed from a regenerating main bed is condensed in the regeneration gas cooler and knocked out in a separator. The remaining water and CO_2 are adsorbed on the regeneration gas dryer bed, from which the dry gas flows back to the main bed. The regeneration gas dryer is regenerated between main dryer cycles. CO_2 is prevented from building up in the closed regeneration loop by occasionally purging some gas to the fuel system.

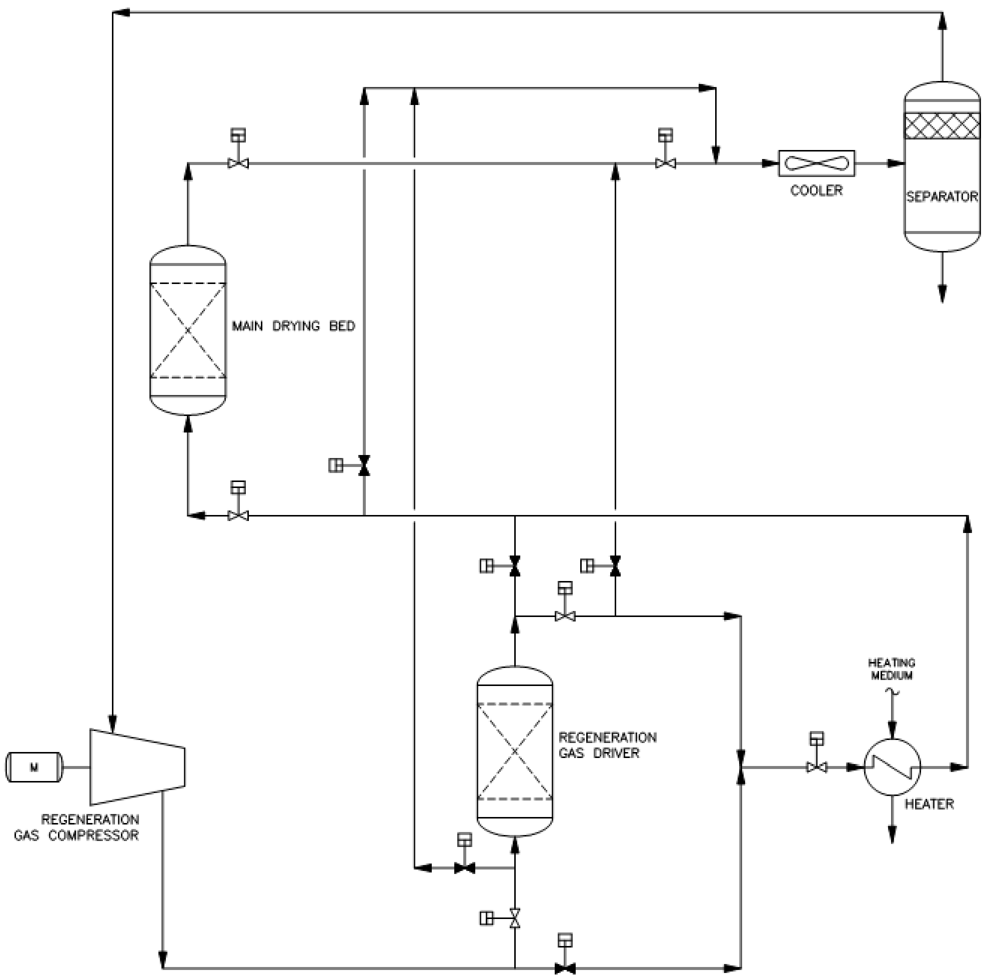

Figure 2. Mole Sieve Dehydrator Regeneration Circuit

Refrigeration Unit. The refrigerant compression and driver configuration is new for LNG plants using the AP-C3-MR™ process. It is comprised of two identical compressor/driver strings. Each of the two strings includes propane, LP MR, and MP/HP MR compressors; with Frame 7EA gas turbine and helper motor drivers located at opposite ends. The plant can operate at reduced capacity with only one string online, which increases the overall plant on-stream time and reduces the potential for flaring incidents.

The typical refrigerant compressor arrangement currently applied uses two strings with different services on each, so that both must operate to produce LNG. The two different configurations are depicted in Figure 3.

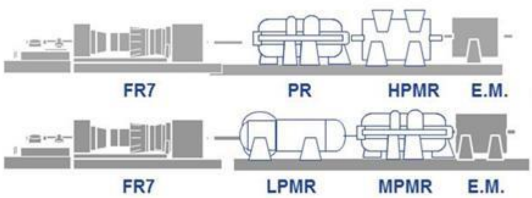

Figure 3a. Typical Compressor Arrangement

Figure 3b. New Dominion Compressor Arrangement

For the Dominion facility, the low pressure mixed refrigerant (LP MR) compressor is a horizontally split casing (MCL1405) and the medium/high pressure MR (MP/HP MR) compressor is a back to back barrel compressor (2BCL806). The propane (PR) compressor is a single horizontally split casing with 3 side-streams 3MCL1405.

The compressors designs were tuned to minimize load sharing control issues during normal and transient operations, focusing specifically on performance prediction to limit performance variability between machines. Very tight tolerances on specifications for head, efficiency, and curve shape at minimum and maximum flow will permit stable operation at any flow within the operating envelope, thus preventing significant differences in loadings between the two parallel strings.

Whenever possible, an impeller identical to one proven by testing has been used. The Dominion compressor impellers are similar to existing designs in operating facilities as shown in Figure 4. The LP MR compressors have been equipped with a recently improved design for high Mach / high flow impellers. These impellers have increased efficiency and higher head rise to surge compared to previous impeller generations.

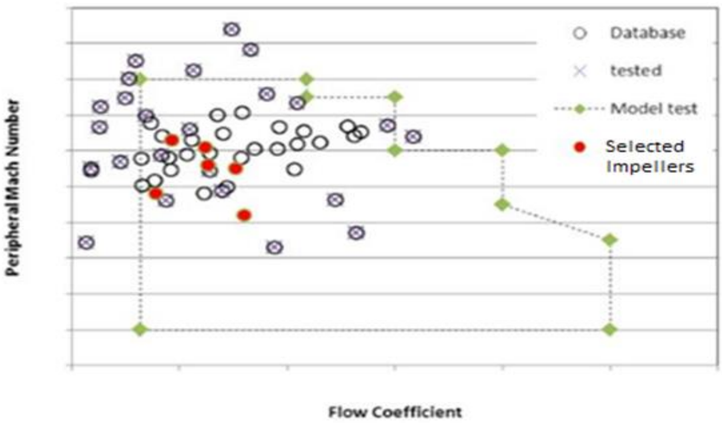

Figure 4. Impeller References for Dominion Cove Point LNG

Gas Turbine Exhaust Heat Recovery. Heat Recovery Steam Generators (HRSG) on both turbine exhausts produce superheated high-pressure steam (SHP) for power generation and process uses, reducing fuel demand for these services and also producing less greenhouse gas. Startup and supplemental SHP is provided by auxiliary boilers.

The gas turbines have dry low emissions (DLE) burners and their exhausts pass through selective catalytic reduction units (SCRs) to bring NO_x emission to levels required by the environmental permit. The CO concentration in the exhaust gas is lowered by catalytic oxidation. The Auxiliary Boilers and Thermal Oxidizer also utilize SCRs and CO oxidation units to further minimize emissions.

INNOVATIVE CONCEPTS THAT MINIMIZE FLARING

Combined Pre-Cool Down and Final Cool Down. The Dominion Cove Point liquefaction project incorporates a procedure to recycle gas during startups, to minimize potential flaring that typically occurs when cooling down equipment to cryogenic temperatures (Figure 5). This innovative procedure maintains the initial cooling rate for the Main Cryogenic Heat Exchanger (MCHE) below the prescribed maximum limit.

The procedure begins with one refrigerant compressor string operating in recycle mode and natural gas in the MR circuit. To initiate cooling, gas from the MR compressors is circulated through the liquefaction equipment.

Pressure reductions across both the light and heavy MR J-T valves cool both MR streams. The two streams flow into the shell of the MCHE and simultaneously cool the shell and bundles. Propane liquid is then added to the MR/propane and feed gas/propane evaporators in a staged manner.

Feed gas flow is introduced at the appropriate time. The cooled feed exits the top of the MCHE and is diverted to a unique Start-Up LNG Vaporizer. This vaporizer is capable of vaporizing enough LNG to start the plant on full recycle. (Initially, the gas stream from the MCHE is still relatively warm and will need only limited heating, if any, but as the MCHE is cooled, the vaporization duty increases.) After passing through the vaporizer, the gas is routed to the suction of the Lean Gas Booster Compressor, which had previously been placed into recycle operation. This enables the gas used in cool down to be recycled and recovered.

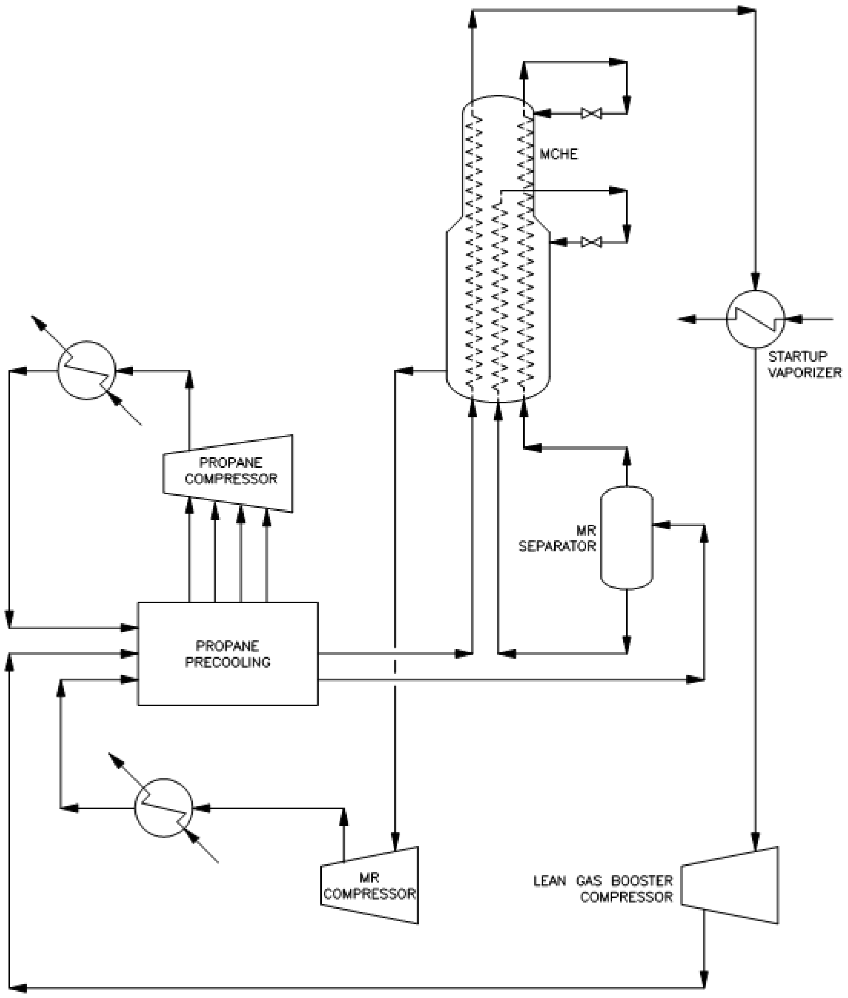

Figure 5. Cool Down Circulation Loop

Recovery Systems for Liquids and Vapors. The Cove Point liquefaction plant is designed with systems to minimize the need to flare various streams that, in the past, have not normally been recovered.

- A Propane Recovery Compressor is used to reduce the pressure on the Propane Compressor prior to startups, thus eliminating the need to depressurize propane to the flare.
- Seal buffer gases vented from all compressors are sent to a dedicated Low Pressure (LP) Vent Collection System that connects to the plant's boil-off gas recovery system. This system also collects vents from online analyzers.
- Liquid MR drained from the MR Separator and other locations is sent to the Refrigerant Recovery Drum. This drum vents light components into the LP Vent Collection System, while liquids recovered are recycled back to the MR Separator for reuse, or to the LNG Drain Drum. The LNG Drain Drum has a heater that vaporizes the liquid into the BOG header.

Zero Liquid Discharge. Waste water from the plant includes boiler blowdown water and brine rejected from the demineralizers that supply makeup water to the amine unit and for boiler feed water makeup. These streams are collected and concentrated in a crystallizer. Solids from the crystallizer are fed to a pressure filter that produces wet solids and a concentrated filtrate. The solids are accumulated and loaded onto trucks for transport to an approved disposal facility.

Water from the concentration process is vaporized, condensed, and recycled to the demineralizers. Thus there are no process waste water discharges from the plant.

Water knocked out during regeneration of the dehydration beds is recycled back to the amine unit. Any heavy contaminants present in the recycle water will be removed with the waste stream from the amine reclaimer.

Noise Mitigation. Buildings, equipment and pipes are acoustically insulated and a 60 ft. (18.3 meters) high wall is being installed around much of the liquefaction plant to meet standards for noise transmission outside the plant boundaries.

Height Restrictions. Another condition for the liquefaction plant required that no equipment could be higher than the tallest existing equipment at the facility. This affected the design of the MCHE and the flares.

The MCHE height limit was met by making the exchanger a two bundle design. This was facilitated by the upstream location of the Heavies Removal Unit. Since mixed refrigerant cooling is not required for heavies removal, a third bundle is not needed.

Ground flares are provided so that flare stacks and flames are not visible outside the facility.

COMPRESSOR STRING PERFORMANCE AND RESPONSE TO UPSETS

Performance Details. Detailed performance tuning was conducted during the design phase to minimize differences between expected and as-tested characteristics. First, the actual flow path from CAD models was used to compare 2D performance analyses to performance prediction tool results. A second step was CFD (Computational Fluid Dynamics) analysis of compressor impeller and stator components. Results from these two steps have been used to tune flow path geometries to match or improve expected efficiencies, operating ranges, and performance curves shapes.

ASME PTC10 Type II tests have fully confirmed the agreement between expected and tested performance with negligible string to string differences as shown in Figure 6.

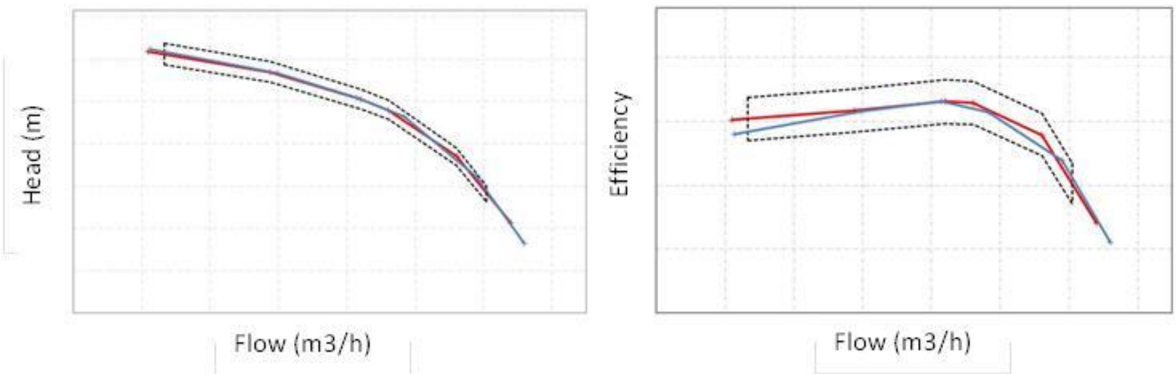

Figure 6. Head and Efficiency: String A (Red) vs String B (Blue) Including Tolerance Range ±2% (Dotted Box)

The new string arrangement required a very long shaft. To reduce compressor footprint without comprising performance, flat end casing designs were used for horizontally split compressors (Figure 7). They have a very compact shaft design accommodating the inlet plenum and discharge scroll just above the shaft ends, minimizing bearing span.

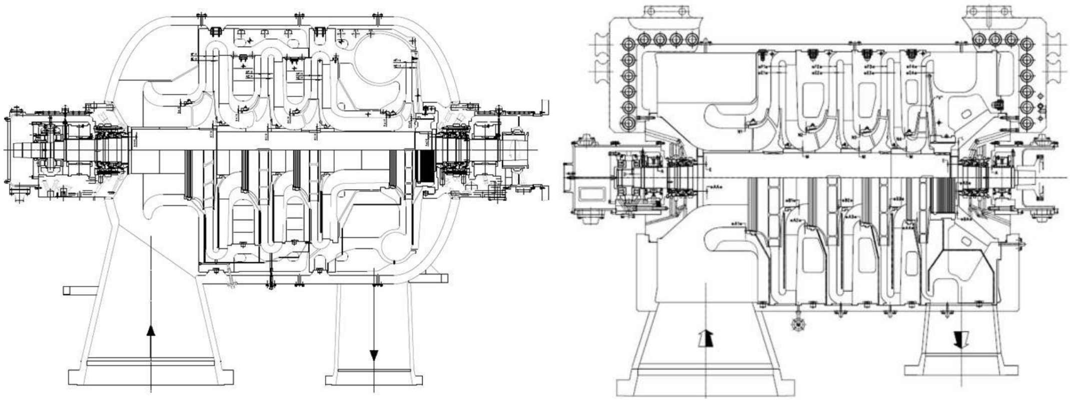

Figure 7 – Round End vs. Flat End Casing Configuration

Dynamic Simulation of Parallel Compressor Strings. With the aim of optimizing parallel string operability, a rigorous dynamic simulation was performed in two phases. In Phase 1, a detailed model of the compression system was developed to study additional protection for compressor surge prevention, driver capability during start up, and to design and size process valves. HYSYS software was used to develop a dynamic model of the PR and MR compression systems.

Scenarios analyzed in Phase 1 were the Emergency Shutdown (ESD) of one string and the start up from zero speed to Minimum Operating Speed (MOS) to verify driver capability. The ESD analysis is critical due to the parallel train configuration. The results showed that in order to mitigate surge and prevent counter-rotation, additional valves were needed. Three PR and one MR Hot Gas Bypass Valves (HGBVs) in addition to fast-closing Suction Isolation Valves were added. The startup analysis is critical because the PR and MR compression system cannot be started from the settle out pressure. The systems have to be partially depressurized in order to allow the Frame 7EA and helper motor to accelerate the string to MOS.

In Phase 2, an advanced dynamic model of the parallel strings was linked to the actual compressor control system being supplied by Compressor Controls Corporation. This study allowed mitigation of potential operability issues, control system testing, and controller pre-tuning, which will benefit commissioning activities.

Several scenarios were analyzed in Phase 2 with particular attention given to the response of a single string trip when both strings were online. Due to the parallel string configuration, the trip of one string generates a refrigeration system disturbance which tends to overload the still running string. If no actions are taken, the operating string may trip due to GT under-speed. The dynamic simulation showed that a trip of the remaining string could be prevented by partially closing the LP MR suction throttling valve and increasing the gas turbine speed to Maximum Continuous Speed **(**MCS) - Figures 8 and 9. These changes must be maintained until the disturbance dampens out.

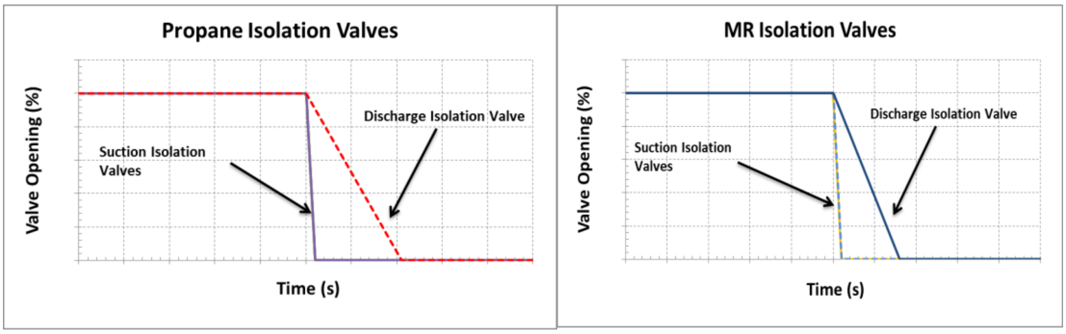

Figure 8. Tripped String, Isolation Valves: PR (left) and MR (right)

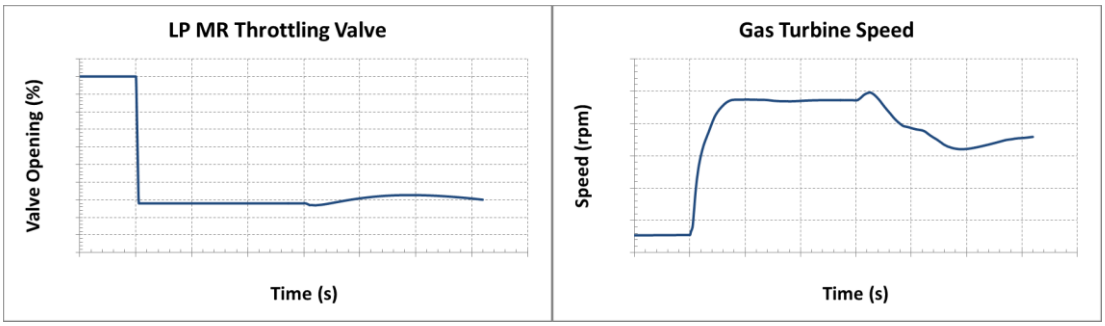

Figure 9. Companion String: MR Throttling Valve (left) and Gas Turbine Speed (right).

The process licensor also performed dynamic simulations of the impact of various upsets on the overall liquefaction process. These simulations included:

- loss of 1 of 2 refrigeration strings and transition to reduced LNG production
- the subsequent restart of a refrigeration string while its companion string is online followed by the transition to full production

Technical information was exchanged to align the separate dynamic simulation efforts and reach a consensus between the parties.

CONCLUSIONS

The Dominion Cove Point project required innovative design features to meet all environmental and regulatory requirements. These challenges were addressed by using new technologies and process features, many of which are implemented for the first time in the LNG industry:

- Recycling feed gas during start–up to minimize the potential for flaring
- Parallel refrigeration compressor strings using industrial drivers in the AP-C3MR^{TM} process
- New main cryogenic heat exchanger cool down procedure
- Closed loop feed gas dehydration system
- Highly efficient islanded power generation system that uses exhaust heat from the gas turbine compressor drivers
- Zero liquid discharge processing facilities.

These requirements are all met within the confines of the existing terminal, which will remain in service throughout the liquefaction integration.

Meeting all of these challenges required close cooperation among all associated parties; including the design and project management team, owner, technology licensor, and major equipment suppliers. The design has been completed and the facility is under construction leading to an anticipated on-stream date of late 2017.