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Ensuring efficiency and reliability of grid-connected eLNG plants

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Electric motor-driven main refrigeration trains [i.e., electric LNG (eLNG)] continue to emerge as a powerful decarbonization pathway for LNG project stakeholders. However, the development of eLNG facilities often presents unique technical challenges not encountered with traditional gas turbine-driven designs. This is particularly the case for plants that use (or have plans to use) the external grid as their main source of power.

Even with highly stable grids, steps must be taken to avoid voltage dips that can impact the operation of the facility, while maintaining a stable frequency under all scenarios. Complexity is often amplified due to the presence of significant harmonic sources in the system, caused by the large electrical motors and drives driving the compression trains. The potential incorporation of intermittent renewables in the future is another factor operators must consider when designing the plant's electrical system.

To this end, evaluating the liquefaction trains—while predicting feedback from the electrical distribution system—is of critical importance.

In this article, the benefits of engaging early in the conceptual phase with original equipment manufacturers (OEMs) to employ an integrated electrical and LNG plant design approach are discussed. Doing so enables operators to mitigate unfavorable electromechanical effects on plant operations, thus maximizing reliability and uptime.

eLNG vs. mechanically-driven trains. Electrically-driven compression trains offer several advantages over traditional gas turbine-driven designs, particularly when it comes to efficiency and carbon footprint.

Electric drives can maintain high efficiency (> 95%) over a wide operating range. This enables operators to decouple the capacity of the compression train from the prime mover. For gas turbine-driven trains, turbines must often be "oversized" relative to the baseload of the plant to accommodate scenarios of fluctuating ambient conditions and operational flexibility, as well as aging and fouling. This is not an issue with eLNG plants, as variable speed drives (VSDs) can be tuned to meet specific LNG production targets.

Electric motors also provide advantages in terms of availability and maintenance. For example, a gas turbine driving an 8-MMtpy compression train has availability of around 95%. After 3 yr in operation, anywhere from 10 d–20 d may need to be allocated for scheduled maintenance. Conversely, electric drives can achieve 99% availability. It is not uncommon for large motors to go 5 yr without scheduled maintenance. Additionally, alternative sparing philosophies of the electromechanical system can greatly extend its maintenance intervals, occasionally enabling uninterrupted maintenance of the drive system. This enables the operators to re-think their overall maintenance philosophy, as the compression system is no longer part of the maintenance critical path.

When it comes to carbon footprint, the extent of emissions reductions that are possible with eLNG will largely be dictated by the source of power generation. Emissions from an industrial open-cycle gas turbine being used as a mechanical drive can be as high as 250 kg CO_2/t of LNG produced. This figure can be reduced significantly with eLNG plants that utilize dedicated combined-cycle thermal power plants.

Even further emissions reduction is possible by adopting hybrid power models that incorporate renewable sources (e.g., hydro, wind, solar and energy storage) in combination with combined-cycle plants. In such cases, renewables or grid electricity can be used as a substitute for gas consumption in the power plant (when it is favorable). Excess power can be stored in batteries and

FIG. 1. Artist rendition of the Woodfibre LNG project. Image courtesy of Woodfibre LNG.

then used for various purposes, including for backup supply in the event of an outage of one or more gas or steam turbines. In this way, electricity generation can be maintained during scheduled and/or unscheduled maintenance events, thereby eliminating the need for an n+1 gas turbine configuration.

Although there are currently no LNG plants in the world that utilize a hybrid power concept, it has been a topic of discussion amongst project developers and engineering, procurement and construction (EPC) contractors and will continue to be evaluated as stakeholders seek out new ways to decarbonize.

Today, the most practical option for low-emissions plant operation is to connect to an external grid that has high renewables penetration (or will in the future). One recent example of this is the Woodfibre LNG project in the province of British Columbia, Canada (**FIG. 1**). The all-electric LNG facility will be located at the site of a former pulp and paper operation. It will be sized for 2.1 MMtpy and utilize clean, renewable hydroelectricity, reducing its greenhouse gas emissions by more than 80% relative to a conventional LNG plant of comparable size.

The authors' company was selected as the single solutions provider for the project and will provide equipment for the main refrigerant trains, including direct-drive refrigerant compressors, high-speed synchronous motors, LCI VSDs, converter transformers, harmonic filters and several e-houses. The project is expected to reach substantial completion in 2027 and begin commercial operation by September of that year. Once operational, Woodfibre LNG will be the lowest emissions LNG export facility in the world.

Design considerations for grid-connected plants. Grid-connected eLNG plants and those that utilize an onsite centralized power plant both present unique technical challenges that are often not encountered with gas turbine-driven compression trains. The primary difference lies in the fact that the design of the onsite power plant can be controlled, which makes it easier to predict the integrated behavior of the electrical system network, thereby making it possible to adjust the overall design to counter any unwanted effects that could lead to a potential trip. With a grid-connected plant, project stakeholders do not have this option as they are required to be compliant to the grid requirements, so the integrated electromechanical compressor design, including peripherals, becomes increasingly important.

A specialized and extensive electromechanical investigation must be performed as the foundation of an eLNG project. Depending on the selected drive technology, the mass and torsional stiffness of the refrigeration compressors contribute towards its torsional natural frequencies, and these frequencies must be "mismatched" from the excitation harmonics that occur naturally within the grid caused by the generators.

This mismatch can be achieved in two ways. First, excitation harmonics can be fixed by the variable-frequency drive's (VFD's) control system by passively or actively "skipping" a few pulses while driving the motor. This disorganizes the pulses and dampens large harmonic amplitude spikes, thus calming the resonance effect. It is important to note that this might impact efficiency throughout the operating range to some extent, since the pulses are responsible for delivering torque to the compressors. Therefore, the strategy would typically be limited to transient scenarios or load cases that are not part of the normal operation of the facility, such as normal offloading.

The second, and most important, mismatch strategy is to map all excitation frequencies and guaranteeing that the torsional natural frequencies of the compressor fall within a range without any sources of excitation. This can be done in two ways. The first option is to change the generator setup, which is impossible for large grids. The second option is by changing the compressor design (i.e., adding a super-dimensioned shaft, different impellers, different couplings, etc). This strategy is 100% passive and preferable during normal operation.

Because of the compressor design's potential impact on electrical system stability, it is beneficial for the compressor OEM to be the one conducting power studies, which is somewhat unconventional, as this responsibility would typically fall on the EPC. In addition, considering that both strategies can be bundled within the OEM scope, the plant risk envelope becomes very simple and equivalent to the traditional gas turbine-drive LNG trains, where the responsibility between the refrigerant compressors and the mechanical drive gas turbines would not be separated. In summary, in eLNG projects, the traditional mechanical drive gas turbines are equivalent to the microgrid within the facility, thus the OEM becomes responsible for its stability under all scenarios.

The importance of early engagement and collaboration. Regardless of whether an eLNG plant uses onsite generation or the external grid for power, it is imperative that interactions and feedback between the liquefaction island and electrical distribution system are modeled and well understood. Historically, the parties responsible for the design and engineering of these two areas have operated separately, often with different approaches.

Where possible, project developers should select partners that possess the expertise to handle the scope for both the compressor design and electrical system, as it will help ensure stability during all scenarios, including steady-state operation, start-up/shutdown and upset events. In this way, operators can achieve the lowest possible emissions profile for their plant, without compromising safety, availability or production uptime. **GP**

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