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Cybersecurity Considerations for the Liquified Natural Gas Sector

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Changing the World's Energy Future

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Analytic Summary

Due to the highly volatile nature of Liquified Natural Gas (LNG) and the systems required for generation and safe containment, it is likely a targeted cyber-attack on LNG control and safety systems will have a significant economic impact on energy supplies and prices. Moreover, if the interconnected operational technology (OT) devices within LNG systems are exploited to malfunction, the repair and recertification process will almost certainly be longer than for natural gas (NG) systems.

LNG vs NG

Figure 1: An LNG carrier docked at a gas terminal island with tanks for storage

LNG is NG in a liquified state and is produced by cooling filtered natural gas to -162 Celsius. NG is liquified to reduce its volume by 1/600th and loaded into super-cooled tanks for significantly more efficient transport over long distances.[1,2,3] Most LNG is transported by sizeable maritime tankers called LNG carriers in large, super-cooled (cryogenic) tanks installed in the vessel.[4] These same tanks can also be found on trucks, rail cars, or at LNG storage locations. When the LNG has reached its domestic or international destination, the regasification terminals reheat and decompress it into its original gaseous form to be distributed primarily through NG pipelines for commercial and residential use.[5,6] By comparison, NG is filtered for combustion in its natural gaseous state and transported via pipelines to resellers, residences, and varying commercial entities. The LNG and NG sectors rely on regulated flow valves, temperature sensors, and supervisory automation systems to manage complex processes, thereby lowering the risk of catastrophic failure.[7]

In 2022, an LNG plant in Freeport, Texas, experienced a massive explosion when a pressure release valve failed to open, causing a pipe to overheat and burst.[8,9] This incident caused significant disruption to LNG production, with global impacts, since it required 8 months for repairs and to obtain the necessary permit clearances to resume operations.[10] By comparison, when a NG company experienced two similar mechanical valve malfunctions, they were repaired the following day with minimal disruption.[11,12]

LNG Equipment

Specialized equipment is required to generate, process, manufacture, contain, distribute, and transfer LNG.

- Main Cyrogenic Heat Exchangers (MCHE) and Coil Wound Heat Exchangers (CWHE) are large towers that perform the work of multiple heat exchangers in the cooling process (see Figure 2).[13] They are comprised of winding coils intertwined to move super-cooled refrigerant alongside NG until it is liquified.[14,15,16]

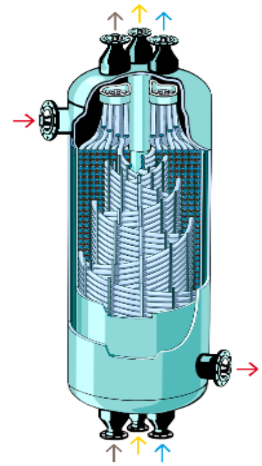

Figure 2: Coil Wound Heat Exchanger

- Compressors are used for movement of NG through the cooling transmission system until the gas reaches a liquified state.[17,18] Frame 7EA compressors are large industrial grade compressors used in the Propane Pre-cooled Mixed Refrigeration (PPMR) liquification process, which are used in 88 percent of all liquefaction plants globally, according to the University of Oklahoma.[19] Frame 7EA compressors can require up to 45 days to install, with industry experts reporting 50 week lead times for a control system HMI upgrade, which extends the timeline to recovery from damage or manipulation of equipment.[20,21]
- Specialized valves, often remotely connected, regulate flow and surge while handling varying pressures. They are designed to function with -162 degrees Celsius LNG passing through the valve while exterior temperature tolerance can be more than 98 degrees Celsius.[22]

Attack Surface Area

The transport and transfer of hazardous materials such as LNG have an inherent risk of system failure.[23] The automation and interconnected nature of systems in the manufacturing, movement, and storage of LNG make them an appealing target for cyberattacks. These attacks have the potential to cause long-term shutdowns from a combination of prevalence within the LNG industry and time required to replace the components, resulting in domestic and international impacts. The interconnectivity of devices including Programmable Logic Controllers (PLC), Supervisory Control and Data Acquisition (SCADA) software, and embedded systems used to perform complex functions raises concerns over cyberattacks targeting these LNG sector-specific devices.[9] Furthermore, new emission regulations for maritime vessels require the integration of modern OT monitoring devices with legacy equipment to assess, in real time, both process efficiency and LNG stability.[24] The merging of outdated legacy systems with the remote capabilities of modern OT equipment likely creates unintentional exploitation opportunities for adversaries.[25]

OT network devices onboard maritime LNG vessels include equipment with functionality similar to onshore terminals, such as flow valves, pressure sensors, and compressors. Most equipment operates within strict parameters using SCADA systems to automate and achieve safe operation standards.[26, 27]

Reliable communication between devices to the SCADA software is vital; however, the addition of more connected devices provides a larger attack surface for potential threats until cyber protections are incorporated and enforced.[28]

Vulnerabilities

Successful attacks against specialized LNG equipment are likely to create significant downtime as a result of the equipment supply and acquisition process.[29,30] OT networks onboard LNG maritime vessels use equipment similar to onshore regasification terminals, according to the Department of Energy (DOE), which means both are likely susceptible to cyber threats.[31,32] Advanced cyber threats were confirmed with the discovery of the INCONTROLLER malware, reportedly designed to target ICS/SCADA devices using generic ICS protocols such as Open Platform Control unified Architecture (OPC UA), which is prevalent in LNG industrial equipment.[33,34]

Sophisticated targeting of critical infrastructure by advanced persistent threat actors using industry-specific malware payloads are likely to increase as remote operations with automation equipment in LNG facilities also continue to grow.[35] Potential cyber-effects ranging from unplanned opening/closing of flow valves and on/off operation of compressors or pumps, in addition to other possible attacks, can lead to damage within the LNG transmission system through a condition called surge. Surge can occur when a transfer system is subjected to a rapid change of flow, such as halting or starting flow unexpectedly, in a self-contained pressurized network.[36] Impacts resulting from surge can be catastrophic to a system, causing damage to compressors and likely shutting down a plant's transmission network for weeks or months for diagnosis and repair, as demonstrated by the Freeport, Texas, LNG incident.[37]

Emergency shutdown (ESD) systems help mitigate the destructive capabilities of surge and are designed to remain dormant until a pressure or flow sensor alert is activated. When activated, loading pumps are halted and powered emergency release coupler (PERC) vent valves are opened to avoid direct damage to equipment and systems further down the line. The shockwave developed by surge travels at the speed of sound, making it exceptionally difficult to monitor or respond to.[38] An analysis of an ESD system application in 2011 reported malfunctions in the ESD system such as vent valves failing to open due to either ESD malfunction or mechanical failure.[39] ESD systems connected to an LNG's facility's SCADA system, surge controller, or flow valves increase the likelihood of a cyber-enabled surge condition by providing malicious cyber actors an access vector to their controls.

Conclusion

Sizeable investments from Qatar Energy and ExxonMobil, paired with record export volumes, reflect the growth of U.S. LNG infrastructure.[40] Persistent targeting of ICS device manufacturers reflects an ongoing interest in obtaining proprietary data and communication protocols related to critical infrastructure equipment used in LNG systems.[41] Moreover, continued reliance on digital technologies within critical infrastructure necessitates increased awareness to emerging threats and particular caution when integrating remotely operated devices.[42] The digital technologies integration process presents an opportunity for cyber-informed engineering practices to be instituted into the design and operation of these facilities.[43,44] If these practices are not integrated from the start, LNG facilities will very likely remain at prolonged risk of cyber-attacks, which will necessitate ongoing reactive mitigations.

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