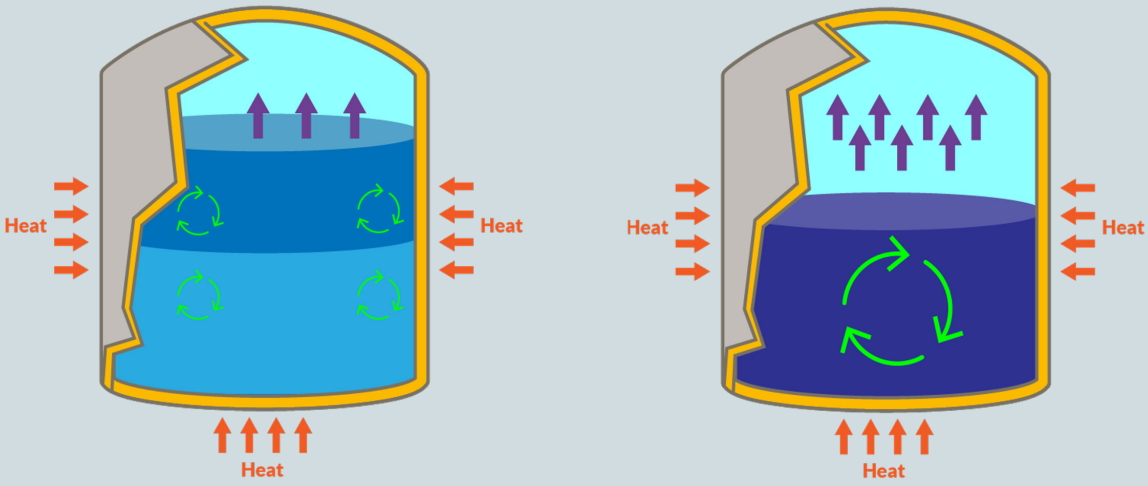
A GROWING LNG MARKET REQUIRES AN INCREASED FOCUS ON OFFSHORE STORAGE SAFETY

As the global need for energy continues to rise, liquefied natural gas (LNG) takes on an increasingly pivotal role in the global energy landscape, offering a flexible and accessible solution for meeting the world's increasing energy consumption while also addressing environmental concerns. LNG is a cleaner alternative to coal and oil and the apparent transition fuel on the pathway towards a net zero society.

Growing energy demand has led to a significant increase in LNG supply and global trade. By the end of 2023, nearly 60 countries had LNG terminals with a combined regasification capacity of 163 billion cubic feet per day (BCFPD), a 16 percent increase from 2022. Additionally, several FSRUs (Floating Storage and Regasification Units) are being built as Europe seeks to reduce its dependence on Russian natural gas.

Offshore LNG storage entails new safety issues

The significant growth in global LNG trade and offshore storage addresses new challenges regarding safety in the LNG industry because they have different characteristics that influence the behavior of stored LNG. In a recent study, "Offshore LNG: Carriers & FSRU storage, operations, and emissions management", the LNG experts at ENGIE analyzed the differences between onshore and offshore LNG storage to identify specific risks and advice on the correct safety procedures. The study concluded that it is urgent to predict and simulate the peculiar behavior of LNG in offshore storage to prevent unwanted events such as stratification, rollovers, pressure increases, and excess boil-off gas (BOG).



Explaining stratification and rollover

When different qualities of LNG is transferred to the same storage tank, it may result in stratification and rollover.

Stratification refers to the layering of LNG within a storage tank driven by differences in density between the LNG initially in the tank and the LNG loaded into the tank. The layers are separated by an interface or buffer zone. Stratification can only occur if denser LNG is placed beneath lighter LNG or, conversely, when lighter LNG is layered over denser LNG.

A rollover occurs when two stratified layers of LNG suddenly mix due to density equalization. Suppose the upper layer, being warmer and less dense, increases in density due to ageing (evaporation of volatile components). The lower layer, which cannot age, absorbs heat, and decreases in density. At a certain point, the interface becomes unstable, causing a rapid release of Boil-off-Gas (BOG), which may lead to venting, flaring, and structural damage.

A stratification that evolves into a rollover implies an increase in the generated boil-off gas up to 10 times the average rate. It may lead to over-pressurization of the tank or lifting of the relief valve of the tanks, thereby posing significant risks to operational safety. A risk is also direct methane and CO2 emissions caused by flaring.

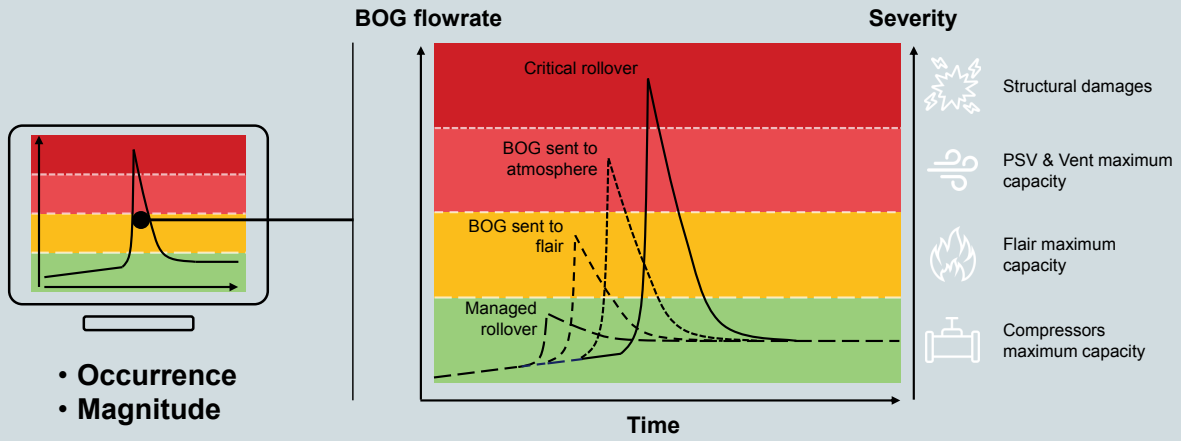
Offshore storage facilities often experience high loading and offloading frequencies from different LNG sources because of supply chain dynamics and limited capacity. However, when LNG is transferred from multiple carriers to the storage tanks in the offshore facility, LNG mixing is no longer systematic, and layers can appear. Therefore, stratification is more likely to occur in offshore facilities and may lead to a rollover. The outcome is a rapid release of BOG, resulting in venting, flaring, and structural damage

Additionally, offshore installations are subject to higher Boil-off rates (BOR) because of tanks insulation design and the fact that they are exposed to weather and sea conditions, resulting in the stored LNG's physical movement (sloshing). The exposure of the extremely cold LNG to the warmer walls of the storage tank results in a further increase in BOG, posing yet another challenge. According to the ENGIE's study, an onshore tank will typically experience a BOR close to 0.08% vol/day, while the BOR in an offshore tank will be between 0.1% and 0.2% vol/day. The higher BOG and a general lack of flexibility (e.g., limited loading capacities and lower BOG management capacities) in FSRUs and FLNGs represent significant risks in case of unwanted events.

According to ENGIE's study, higher BOR and sloshing in an offshore facility shorten the time rollovers occur after stratification. Higher BOR leads to greater heat ingress in the tank, and the temperature increases more rapidly. Regarding the upper layer, methane and nitrogen evaporate faster, and ageing is accelerated. Thus, the upper layer density rises more quickly. A higher BOR also has consequences on the lower layer. More energy accumulates, increasing the BOG peak at rollover. Therefore, higher BOR in offshore infrastructures implies faster and more severe rollovers.

Reducing risks in LNG offshore storage

The study by ENGIE emphasizes the urgency of effective preventive measures and safety protocols to increase the safety of offshore LNG storage. That is why ENGIE and Svanehøj have partnered to maximize synergies between ENGIE's LNG simulation software and Svanehøj's instrumentation solutions and tank control systems.



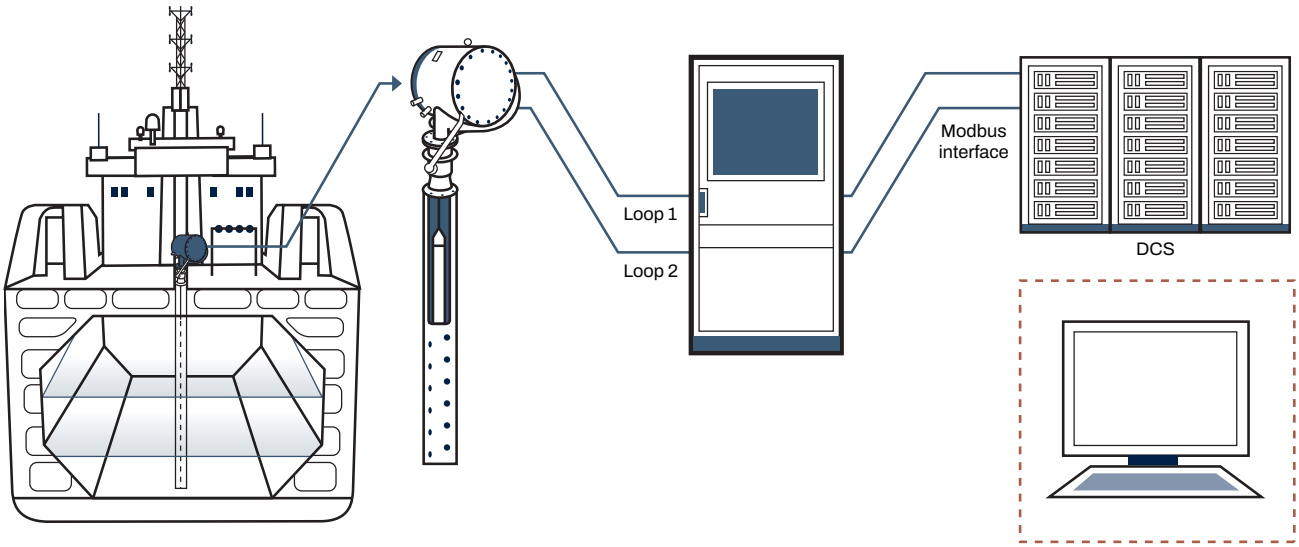
LNGMaster: Predicting the LNG behavior in LNG storage

LNGMaster is a simulation software developed by ENGIE that can simulate several scenarios to predict LNG behavior, particularly the rollover phenomenon. The software relies upon physical modeling of the main heat and mass transfer processes in a stratified LNG tank.

ENGIE is an expert in LNG behavior in the storage phase. For fifty years, ENGIE has conducted studies to understand LNG better and predict its evolution. Based on this extensive knowledge, the company developed the LNGMaster software solution to predict stratification occurrence and simulate its evolution to rollover accurately, indicating the date of occurrence and the BOG peak produced.

LNGMaster has been used in several studies for design purposes, such as dimensioning BOG compressors and safety solutions, as well as operational tasks.

Data is the cornerstone of effective decision-making and operations, and LNG management is no exception. As LNG storage facilities handle and store multiple grades of LNG, the chemical composition of any stored LNG is in constant flux. Therefore, monitoring the storage tanks and being warned of any occurrences is vital. LNG storage facilities must have precise instruments that measure temperature, density, and level variations.



Complete monitoring and control solutions for offshore LNG storage

Svanehøj Tank Control Systems provides both stand-alone products and total safety solutions for the offshore storage of LNG, designed to reduce risks in LNG storage by providing the highest levels of accuracy, reliability, and repeatability.

The system consists of:

· Fully automated LTD gauges · Fully automated rollover predictive alarm software · Tank data acquisition system

Level, temperature, and density (LTD) gauge

A specialized marine version of the M1146 LTD Gauge is a key instrument in Svanehøj's range of offshore LNG storage safety products. It is the lightest gauge in its class, designed to provide highly accurate data on level, temperature, and in-tank density measurements.

Rollover Predictor

The LNG rollover predictive software monitors the evolution of the layers of LNG in the storage tanks. It handles all grades of LNG and estimates the evolution of the chemical composition in real-time. The forecasting tool includes an automatic mode that calculates the chemical composition using data on density, temperature, and operating pressure collected from LTD gauges.

The rollover predictive software requires a chemical composition to initiate the calculation process. Svanehøj's rollover prediction platform is directly linked to the terminal's distributed control system (DCS) in a fully automatic process based on measured parameters (density, temperature, and operating pressure).

Tank Data Acquisition System (TDAS)

The TDAS is linked to the field instruments and the distributed control system (DCS). The system is PLC-based and includes all necessary I/O modules. It is fully redundant (power supply, I/O modules, CPU) and provides hot standby with Achilles Level 2 certification to ensure a high level of security against malware, spyware, and virus attacks. ▸

Svanehøj's instrumentation and safety systems for cryogenic and refrigerated storage are installed with ENGIE's LNGMaster software to ensure that all hazardous aspects of the storage tanks are known and controllable. The precise instruments, capable of detecting even the slightest temperature, density, or level discrepancies, are critical in this high-stakes environment, enabling operators to make well-informed decisions that optimize storage processes and uphold safety standards.

Svanehøj: A one-stop-shop of integrated safety solutions and services

Navigating the complexities of safety in LNG storage requires precision, reliability – and partners with an in-depth understanding of this specialized field's intricacies. With its extensive experience and global presence, Svanehøj Tank Control Systems is a market-leading provider of safety solutions for the storage of liquified gas and was the first supplier to develop a level, temperature, and density (LTD) gauge for floating storage. Today, more than 300 vessels worldwide are equipped with Svanehøj's LTD gauge.

Svanehøj Tank Control Systems was established in Calais, France, in 1961, as Whessoe plc. The company equipped its first gas carrier in the 1970s and its first LNG storage tank in the 1980s. Since 2021, the company has been an integral part of Svanehøj, which have initiated extensive investments in products and services.

The strategy is to offer total solutions by providing the overall system for monitoring LNG and LPG tanks while also handling the subsequent servicing over the facility's lifetime. A one-stop-shop partnership based on decades of experience.

Svanehøj's calibration lab in Calais, France, specializes in certified sensor calibration for all servo-driven LTD gauge brands in the market, establishing a reliable standard for accuracy and dependability in operations. This service ensures clients have the necessary tools for sound decision-making and uninterrupted workflows.

ENGIE: A pioneer in studies on LNG behavior

Over the past fifty years, ENGIE has embarked on research to understand and predict the behavior of LNG, leading to the creation and continuous refinement of various models. These physical and thermodynamic models have been validated in diverse settings, including the former GDF "Cryogenic Test Station" in Nantes and the Montoir de Bretagne Elengy LNG terminal.

Leveraging this comprehensive understanding, ENGIE's R&D center developed the LNGMaster software, adept at predicting the onset of stratification and simulating its progression to rollover, providing precise forecasts of its occurrence and the resulting BOG peak.