THE ADRIATIC LNG TERMINAL: INDUSTRIAL FIRSTS INTO A FULLY OPERATION REALITY

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ABSTRACT

The Adriatic LNG Terminal, located about 15 kilometres off the Italian coastline in the northern Adriatic Sea, is a state-of-the-art facility created to provide the domestic gas market with a major new, safe and reliable source of energy. Inaugurated on October 2009, the Adriatic LNG Terminal more than trebles Italy's LNG import capacity with a nominal regasification capacity of 8 billion cubic meters per year (775 million cubic feet of natural gas per day). This represents approximately 10% of the country's natural gas consumption, thus helping to diversify and improve national security of supply. 92% of the regasification capacity is committed to long term contracts and the Terminal has been operating at utilization rates of around 85% since start-up. LNG Carriers arrive at the berth for unloading on average every 4 - 5 days. Safety and reliability performance has been excellent – the Terminal recently exceeded one year without a recordable safety (personnel or process related) or environmental incident. The paper describes the technical and operational achievements of this unique LNG Terminal, highlighting some of the challenges associated with running the world's first offshore concrete gravity base LNG facility. The tremendous achievements of the young Adriatic LNG organization have been made possible by the strong support of its shareholders. The paper will also describe how this standalone joint venture company has benefited from their support.

INTRODUCTION

The Adriatic LNG (ALNG) Terminal, located about 15 kilometres off the Italian coastline in the northern Adriatic Sea, is the first offshore Gravity Based Structure (GBS) for unloading, storing and regasifying Liquefied Natural Gas (LNG). The ALNG Terminal is a state-of-the-art facility created to provide the domestic gas market with a major new, safe and reliable source of energy. Inaugurated in October 2009, this facility more than trebles Italy’s LNG import capacity with a nominal regasification capacity of 8 billion standard cubic meters per year (775 million cubic feet of natural gas per day), which represents approximately 10% of the country’s natural gas consumption, thus helping diversify and improve national security of supply.

The ALNG Terminal was designed, built and is now operated by Terminale GNL Adriatico Srl, commonly known as Adriatic LNG, an Italian company established in 2005 by Qatar Petroleum, ExxonMobil and Edison.

The importance of this infrastructure has been recognized by Italian and European authorities. The Terminal has been declared a project of Italian and European strategic interest respectively by CIPE (Interministerial Institute for Economic Planning) and by the EU Commission.
Figure 1 – The Adriatic LNG Terminal

The ALNG Terminal Project required the management of a large array of technical and governmental interfaces and the introduction of several new technologies and industry firsts to bring gas product to a previously inaccessible market, including:

- First concrete Gravity Based Structure (GBS) used for an LNG terminal,
- First application of proprietary Modular LNG storage tank technology, used to enable the tanks to be constructed in parallel with the GBS structure.
- First application of specially adapted LNG offloading arms designed for operation in more exposed meteorological and marine conditions.

Eighty percent of the Terminal capacity (about 6.4 billion standard cubic meters per year, bcm/y) is utilized by Edison for a period of 25 years, to regasify LNG imported from Qatar’s North Field, through a supply and purchase agreement with RasGas. The remaining 20% (about 1.6 bcm/y) is open for third party access and is allocated according to the procedures defined by the Italian Ministry of Economic Development and the Regulatory Authority for Electricity and Gas. Currently twelve percent has been allocated.

With over 3 years of operational experience, the Terminal has proved to be a reliable facility providing dependable services of high quality and added value to Italy. More than 250 LNG carriers have successful unloaded with a reliability rate around 99.9%.

OBJECTIVES OF THIS PAPER

This paper describes the technical and operational achievements of this unique LNG terminal, highlighting some of the challenges associated with running the world’s first offshore concrete gravity base LNG facility in the Italian regulatory environment. The tremendous achievements of the Adriatic LNG organization have been made possible by the strong support of its Quotaholders.

ADRIATIC LNG TERMINAL DESCRIPTION

The ALNG Terminal is a unique facility utilizing innovative technology to provide a safe and efficient offshore LNG offloading, storage, and re-gasification capability. The terminal is a large gravity based structure (GBS) resting on the seabed at 29 meters (m) mean sea level.
The structure is 180 meters long by 88 meters wide, with a height of about 47 m. Approximately 90,000 cubic meters of concrete were required to build the GBS. Constructed weight of the facility is approximately 290,000 metric tonnes (mt); the installed weight after adding solid ballast at the installation site is over 640,000mt.

![Figure 2 – Major GBS Components](image)

The GBS contains two LNG storage tanks with a total working capacity of 250,000 cubic meters, approximately twice the capacity of a conventional LNG carrier. The recently developed Modular LNG tank technology has been used to enable the tanks to be constructed in parallel with the GBS structure, while meeting all required safety and performance standards.

Approximately 20,000 mt of topsides and mooring facilities are installed directly on the GBS structure. Major process equipment includes four in-tank LNG pumps, five high-pressure send-out pumps, four Open Rack Vaporizers (ORV's) which use seawater as the heating medium, a Waste Heat Recovery LNG Vaporizer (WHRV) which uses waste heat from the turbine generators, and two Boil Off Gas (BOG) compressors. One of the in-tank LNG pumps, one high-pressure LNG pump, and one ORV serve as spare equipment. Four centrifugal pumps, with a capacity of about 7,000 m³/h each, supply the seawater needed for vaporization purposes to each of the 4 ORVs. Three gas turbine generators (GTGs) provide approximately 31.5 Mega Watts (MW) of electric power.

Living quarters are provided on the terminal for up to 60 people.
SAFETY, HEALTH AND THE ENVIRONMENT (SHE)

The goal of Adriatic LNG management is to operate with zero injuries or occupational illnesses, zero spills or regulatory exceedances and no significant loss of containment, equipment damage or business loss. Management’s first priority is to systematically control risk by ensuring the effectiveness of the Company’s integrated Safety, Security, Health & Environmental Management System (SHEMS).

Most significant initiatives and results achieved in the SHE area over the first 3 full years of commercial operations are depicted below.

SAFETY, SECURITY, HEALTH & ENVIRONMENTAL MANAGEMENT SYSTEM (SHEMS)

ALNG has implemented an integrated Safety, Security, Health and Environmental Management System (SHEMS) which has continued to progress since before production started. The Quotaholders have been instrumental with supporting development, implementation and assessment of SHEMS.

SHEMS Assessments of ALNG are conducted on a periodical basis by multidisciplinary and experienced teams. The Team typically conducts interviews with the ALNG management and personnel, reviews SHEMS documentation, and observes operations at the Terminal, the Shore Base and Metering station.

The last Assessment was conducted in June 2012. The Team concluded that ALNG has undertaken substantial initiatives to promote SHEMS throughout the local organization, and significant improvements have been made since 2010. ALNG was assessed at an overall status and effectiveness score that displays the maturity of the system.

A regulatory audit per the Major Accident Prevention (“Seveso”) regulations was also positively concluded by the Italian Government in July 2010. The auditors reviewed SHEMS, various documents and made 11 visits to the facilities over a 6 month period. No significant issues were raised.

SAFETY

From a Personnel Safety perspective, the Company relentlessly pursues an incident-free workplace. This effort has continued over the years since the Project phase. Leadership and guidance is provided through
the management team, three Safe Operating Committees (SOCs) at the Terminal, Shorebase and Milan office and various Work-Site Safety Committee Meetings (WSSCs).

Many safety initiatives have been put in place since start-up, with Quotaholders support. Recently, in 2012, ALNG management implemented a behavior based safety program using the Loss Prevention System (LPS) to further support the effectiveness of SHEMS. LPS is a proven third party proprietary system that focuses on behavior, targeting conditions and environmental factors, making incident reduction a part of normal work activities. LPS has been rolled-out through the organization, and LPS tools have been integrated in the existing SHE/SOC/WSSC Committees at all levels of the organization, whilst stewardship and reporting are now being finalized.

The Loss-Ratio Triangle, one of the fundamental concepts behind LPS, is utilized in ALNG to monitor the pattern of losses. Specific personnel and process safety triangles have been revised to better meet LPS requirements, are stewarded monthly and shared at all company premises.

Supporting the safe performance of contractors is another key focus area of ALNG management. Integrity critical key contractors were involved in the LPS roll-out. A structured process to regularly assess and communicate contractor SHE performance is in place, and annual contractor safety workshops are held to maintain alignment with safety duties and obligations per contract.

Various laws and regulations related to safety apply to the Company’s activities. The most significant of these is the Major Accident Hazard Prevention (“Seveso”) Law. The Company’s Safety and Major Incidents Prevention Policy was first issued in 2009 and, according to biannual mandatory review, it was revised in 2011, after a consultation process that involved and collected input from key parties within the organization, including the Workers’ Safety Representative.

A safety leadership workshop, Fundamentals of Safety, was conducted in 2011 and is now planned for 2013, including LPS principles.

From a Process Safety perspective, ALNG put in place a strong program to monitor the efficiency of those processes that are relevant to prevent actual events from occurring such as Loss of Primary Containment. Any overdue temporary MOCs, overdue Integrity Critical Work Orders maintenance-related, overdue actions from Risk Assessments, defeated alarms, demand on safety systems, and small losses of primary containment are tracked and reported to management on a monthly basis and specific actions taken to work and steward the resolution plans.

Loss of Primary Containment events went down from 1 in 2010 to 0 in 2012.
HEALTH

In Italy, Legislative Decree 81/2008 lists the general safety and health protection measures of workers at work. Some of those health-related measures are identified below along with the activities that Adriatic LNG has undertaken:

- A single point occupational health risk assessment is issued and revised periodically for different Company locations, which generate a yearly improvement plan agreed with the Workers Safety Representatives.
- Monitoring/assessment studies of the microclimate in the living quarters, noise levels and explosive atmosphere risks at different facilities and areas are issued and monitoring campaigns are executed.
- An Office Ergonomics Program was initiated in 2011 and is refreshed periodically, with Office Ergonomics Contacts classroom training and Company personnel e-learning awareness training.
- Consultation and participation of worker safety representatives is formally achieved via an annual meeting with the management, as well as via consultation on health policies and selected projects.
- An extensive health surveillance plan for employees at different Company locations. Medical examinations are carried out periodically, under the supervision of the Company’s doctor, to check the state of worker health, or at the request of the worker, at the time of a change in duties or cessation of the employment relationship.
- An infirmary with a physician is set up offshore for first aid, emergency medical care and provision of general consultation for workers while on board. Medical evacuation (medevac) arrangements and coordination procedures are in place with the regulatory agencies and local hospitals. On a daily basis the offshore physician is informed and consulted for those permits to work requiring use of chemicals through the analysis of MSDS documentation.
Training and information to workers is an ongoing activity at all locations.

ENVIRONMENT

Company operations from an environmental perspective are strictly regulated. The overall impact of Terminal operations on the environment was assessed and environmental monitoring plans established within the Environmental Impact Assessment (EIA) Decree issued by the Italian Government on the 30 December 1999. All emissions, both to water and air, as well as waste are controlled by the Integrated Pollution Prevention & Control (IPPC) Permit (AIA, Autorizzazione Integrata Ambientale) issued in 2009. The IPPC package for permit renewal is due for submittal in 2013.

Adriatic LNG is required to participate in the European Union Emissions Trading System (ETS) which sets strict measurement requirements for CO2 emissions and necessitates CO2 allowances to be submitted to the regulator to cover all CO2 emissions. ETS Phase 2 covered the period 2008-2012, during which time the Company qualified for certain credits due to the utilization of a Waste Heat Recovery System. In the European Emissions Trading Scheme Phase III (2013-2020), Adriatic LNG will experience a 77% reduction of CO2 credits for 2013 versus the 2012 level of assigned credits. From 2013, the CO2 credits will decrease each year until reaching 30% of 2013 levels in 2020.

The primary source of CO2 emissions for Adriatic LNG is the fuel gas consumed in the gas turbine generators, representing more than 96% of total CO2 emissions. The rate of emissions is therefore linked to the demand for power, which in turn is linked to the rate of regasification commensurate with the demand of sea-water pumps, in-tank pumps and send-out pumps. The secondary source of CO2 emissions is from flaring, the majority of which occurs during shutdown events. The flare emissions have continued to decrease since start up, indicating the increasing ability of the operating organization to manage shut down events, when boil off gases from the LNG storage tanks are routed to the flare.

The IPPC permit identifies, limits and specifies how to monitor relevant environmental parameters. The most significant ones are:

- NOx and CO concentration from Gas Turbine Generators stacks, limited to 50 and 40 mg/Nm3 respectively when electric load from each GTG exceeds 50%;
- Free active chlorine concentration from sea water discharge, limited to 0.2 ppm;
- Yearly average sea water temperature difference (delta T) between inlet and outlet, limited to -4.6°C;
- Maximum number of days per year for running 4 sea water pumps (i.e. 4 Open Rack Vaporizers) is limited to 80.
The sodium hypochlorite injection into the strainers at seawater pump intake for ORV water, firewater and service water has helped successfully control fouling caused by biological growth in seawater piping while at the same time maintaining efficient heat transfer across the LNG Open Rack Vaporizers. The cleaning program for the water troughs located on top of the vaporizer panels, where the water is evenly distributed onto the heat transfer surface, has been optimized by taking advantage of a strong surveillance program that was developed for the equipment.

The observed yearly average seawater delta T has remained well within the established regulated limit during the 3 complete years of operations experience. The seawater delta T is dependent upon the actual seawater temperature and LNG throughput. The delta T tends to be closer to the limit during the summer when producing high rates on occasions, whilst the delta T values are relatively low in the winter when less heat is available from the sea even when producing high rates.

The ability of Operations to meet specific engineering guidelines for operating the seawater pumps has provided the benefit of effectively managing the maximum permitted number of days for using 4 seawater pumps.

The extensive environmental monitoring plan being executed by the regulatory agencies in the waters surrounding the terminal is showing that the chlorinated and cold plume disperses within 100 m from the terminal under a wide variety of meteocean conditions, not affecting the sea bed and with no measurable consequences for marine life. The extraordinary efficiency of the discharge point to disperse the plume is obtained due to the high turbulence created by the layout of the water outlet, constituted of three square openings located 12 m below the sea level in the GBS compartment from which the water is discharged.

Formation of foam from the sea water discharge is being observed due to air being entrained in the sea water as it passes through the process, and bubbles are formed aided by the biological organic matter existing in the Adriatic Sea acting as a surfactant. The Ministry of the Environment recognized that foam does not create harmful impacts on the environment or health. However further monitoring is being developed and full scale testing of anti-foam agents are being designed. Other potential solutions to mitigate foam formation are being evaluated.
CHALLENGES AND ACHIEVEMENTS SINCE START-UP

As said, the ALNG terminal is a unique facility combining a number of industry firsts. The nature of this terminal and specific design choices have translated into a number of challenges from an operationing viewpoint and were to be tested to confirm effectiveness. For the purpose of this paper, a few areas are described to illustrate issues that have been faced since startup have successfully been resolved by the operating organization while continuously offloading, storing and regasifying LNG to provide a reliable supply of energy to the Italian network.

The following are the fundamental topics covered in this part of the paper:

- The terminal is equipped with a new, patented concept of LNG storage tanks, modular type, that were to be cooled down for the first time ever. This paper describes the key steps from first LNG carrier accommodation to cool-down and further, to first gas and to regular LNG carriers berthing every four days, per design.

- Once hydrocarbons are introduced and facilities cooled down, severe restrictions are in force from a work management perspective to ensure safety. Yet, as typical for the post-startup phase of large process plants for hydrocarbons, issues arise with facilities in their infancy, which translate into opportunities for facility modifications and Management of Change (MOC). Also, selected regulatory certifications need running facilities for completion. How significant these items have been and the organizational approach to effectively tackle them are outlined below.

- The terminal is located offshore, with no port infrastructure to shelter the berth from winds and waves. Terminal orientation with respect to prevailing winds and waves was key, and LNG offloading arms were equipped with special features for an effective connection with the LNG carriers manifold while accommodating carriers movements under a variety of meteocean conditions. The extent of berth downtime associated with weather events and impact on production continuity and demurrage claims raised from affected parties are also dealt with below.

- This facility was planned to become a strategic component of the Italian gas network, with the aim of expanding the number of natural gas sources and increasing security of supplies to the country. There have been practical cases where ALNG helped securing supplies continuity to the country over the course of the first three years of operations.

- The general vicinity of the ALNG site is characterized as one of moderate seismicity. Recent dramatic seismic events in North-Eastern Italy have caused multiple deaths. The concept of a concrete GBS hosting LNG storage facilities is an industry first. Seismic design criteria have then been tested during recent events, and structural behavior monitored to confirm design outcomes.
FROM COOLDOWN TO DESIGN CAPACITY

In only 3 months from when the LNG Carrier S/S DUKHAN commenced berthing at the Terminal (10 August 2009) for initiating cooldown operations, ALNG achieved accommodation of maximum number of LNG cargos in a month per design. Here are the key steps for how this was accomplished.

The piping and Tank #1 were gradually cooled down first in preparation for introduction of LNG. The required temperature was reached on the 25th of August and then pumping the LNG cargo of the Duhkan into Tank #1 of the terminal commenced. On the 28th of August the cargo was fully discharged into the terminal and the Dukhan departed. The next step was to use the LNG in Tank #1 to slowly cool tank #2 in preparation for second cargo arrival and the start of gas sendout operations into the national pipeline grid. On the 6th of September, gas sendout into the Italian National Grid commenced from the ALNG terminal, at a rate of approximately 3 Million Standard Cubic Meters a day (Mscm/day). Sendout was maintained cycling through various combinations of pumps and vaporizers. The rate remained at this level for few days and was gradually increased over the following weeks while the facility was fully tested. In parallel with this activity the LNG carrier Maersk Ras Laffan was unloaded into tank #2 including successfully managing a weather disruption requiring a disconnect in the middle of the unloading activity. The carrier was then re-moored and completed her discharge.

These two milestones of safely cooling and filling the two tanks and commencing sendout were historic for ALNG and the Italian market.

On 24 November, ALNG awarded the first spot capacity slot through a regulated, competitive Third Party Access (TPA) tender process.

In November 2009, 8 cargos were unloaded. Several weather events and several unanticipated downtime events were successfully managed, and meeting the monthly sendout plan. Remaining project activity related to punchlists and close out items were transitioned to the operating organization. November 2009 also represented ALNG’s first month of normal operations under the Foundation Capacity Agreement between the parties.
POST-STARTUP WORKS

The post-startup/early operation phase was characterized by the need for the operating organization to progress few relatively significant punchlist items, handle a significant number of MOC items, while at the same time ensuring continued operations. The most significant items were grouped in a single project scope and managed by a project management team, with members from the Quotaholder, the operating organization and the main EPC contractor.

The main items from the punchlist were:

- The Waste Heat Recovery LNG Vaporizer, a shell and tube heat exchanger, was upgraded to enhance resistance to Stress Corrosion Cracking via application of Thermal Spray Aluminum coating applied to the shell.
- New impellers and diffusers were installed to the LNG in-tank pumps to align the outlet pressure to piping rating.
- Lifeboat davits were modified to avoid clashes with the GBS while lowering the boats.
- The tethering system of the 4 marine fenders, those devices linked to the breasting structures where the LNG carriers come alongside the terminal to damp the marine loads, was modified so to strengthen fenders connection to the steel structures and improve behavior under severe weather conditions.
- The supporting and retrieval system for the strainers placed at the inlet of sea water pumps was also modified to better withstand severe environmental conditions and loads from air burst.

Certifications of those topside systems that require the facility to be operating for testing and sign-off from a regulatory perspective were issued in this phase. In particular, process and utilities pressure systems certification per European Pressure Equipment Directive (PED) required extensive surveys from a third party to confirm systems work per design and within the operating envelop. Findings from this exercise were incorporated into release of the as-builts for the affected project documents.

Environmental-related devices, key to monitor those parameters stipulated in the permits such as NOx and CO concentrations from air emissions, went through commissioning and calibration during early operation phases. The Continuous Emissions Monitoring System (CEMS) for the flue gases from the GTG stacks was completely replaced for both hardware and software to meet regulatory requirements.
Also, the fire-fighting system for the helideck was modified to meet newly emerged regulations. Specifications for a more concentrated foam required additional tanks and enhanced distribution piping.

Finally, LNG custody transfer operations were improved thanks to specific modifications to the LNG sampling skid as well as LNG offloading procedure and enhancements to the sampling and monitoring practices. Other selected modifications were implemented to different measurement systems both on the terminal and at the gas metering station located onshore, that allow gas measurement accuracy to remain well within industry standards.

The majority of these works were completed in 2010 and some were carried over in following years, with no impacts on operations continuity and under increasing reliability indicators.

Figure 8 – LNG Carrier Berthing

WEATHER EVENTS THAT CHALLENGED FIRST 3 YEARS OF OPERATIONS

The particular position of the ALNG terminal, located offshore with no port infrastructure to protect it from exposure to severe weather conditions, was known as being a peculiar aspect with potential consequences on LNG carriers berthing and offloading operations that may affect terminal reliability.

As a matter of fact there have been specific weather events that tested the effectiveness of marine operations and associated meteocean criteria, as well as the ability of the operating organization to manage them.

The Adriatic LNG installation is under the influence of the Northern Adriatic climate which is known for fast variations in weather conditions. The main winds in the area are the Bora and the Scirocco. The most noteworthy aspect of the Bora is that it sometimes spills out of the mountains with an abrupt rise in velocity, spawning squalls and yielding wind speeds of 55 to 70 knots within a couple of hours that can typically last 0.5 to 2 days. The Scirocco emerges from the South as tropical continental air that has lifted up moisture from the Mediterranean Sea and produce winds that last from 1 to 3 days.

LNG carrier marine operations are limited by meteocean criteria set by the Harbour Master office via specific Navigational Safety Order. Limits for mooring operations are set at 1.5m significant wave height and 25 knot omnidirectional wind velocity; limits for unmooring operations depend upon direction and vary from 1.7 to 2.5m significant wave height, and from 30 to 36 knot wind velocity.
In February 2010 ALNG experienced some weather events that resulted in two tankers in quick succession mid-month then a reduction in send out to conserve inventory pending the weather improving near the end of the month. These were well managed by operations avoiding tank tops and minimum inventory, and ultimately the month resulted successful for ALNG with 7 cargos unloaded in a short month.

At the end of January 2011 ALNG experienced a prolonged weather event during which fender number 4 (the only one not yet upgraded at the time; fenders 1 – 3 withstood the weather well) was lost. The organization was able to safely install a spare fender when the weather calmed down and unloaded the carrier Al Areesh a few days after the event occurred. The 4th fender was then quickly located and recovered and the month ended with 7 cargos offloaded.

During February 2012, a period of extremely cold weather was experienced in Europe bringing wind velocities and wave heights approaching the 100-year storm, thus resulting in a Gas Emergency being declared by the Italian Ministry of Economic Development. Despite the extended berth unavailability and the very low sea water temperatures (6-7°C) which affect heat transfer on the Open Rack Vaporizers, send-out operations were not interrupted and gas flow rates were maximized to peak capacity as soon as winds and waves permitted to catch up deferred volumes, thus contributing to quickly reconstitute inventories in the national network’s gas storage facilities and ensuring energy supplies continuity to the country with no power outages.

Notwithstanding the severe weather events that occurred with an yearly period, the monthly gas re-delivery plans were never significantly affected, as the reliability data confirms in another paragraph of this paper. This demonstrates the sound overall performance of the plant at different sendout rates, including the peak rate, as well as equipment reliability at peak rates. Also, the above weather events and the course of actions that followed show the ability of the operating organization to manage inventories and LNG carriers logistics under challenging circumstances.

**OTHER GAS EMERGENCIES DECLARED BY THE ITALIAN GOVERNMENT**

Other Gas Emergencies were also declared by the Italian Government in 2010 and 2011.

The Transitgas pipeline (import route for gas from Norway & the Netherlands) was shut down in July 2010 and remained out of service for several months until late December 2010 due to a landslide near Guttannen in Switzerland, and the Greenstream pipeline supplying gas to Italy from Libya was shut down in February 2011 and re-opened no earlier than October that same year.

ALNG constructively worked with the Government and clients on these occasions, responding to the gas system needs by providing the requested flexibility, modulating or maximizing sendout rates and securing a few spot cargos with users.

In July 2011, 7 cargos were safely unloaded thereby reaching 150 cargos from inception-to-date. The year 2011 was at the same time of the 150th anniversary of the Union of Italy so the organization celebrated this milestone given the excellent performance and confirmation of the strategic role that Adriatic LNG is playing for the country.

**SEISMIC EVENTS IN NORTH-EASTERN ITALY IN MAY-JUNE 2012**

Several seismic events with multiple deaths occurred in North-Eastern Italy in 2012 during the time period between May 20th and June 3rd with the epicenter in Emilia-Romagna, approximately 100 km from GBS. The two highest earthquake intensities were recorded on May 20th (6.1 Richter Scale Magnitude), and on May 29th (5.1 Richter Scale Magnitude). This unfortunate occasion has been an opportunity to test the terminal design criteria for seismicity and verify structural response of the GBS and LNG storage tanks.
A dedicated analysis of the SGMS (Structural and Geotechnical Monitoring System, monitors GBS structural response in case of normal conditions and during exceptional events, for example seismic activity, or high loads from wind, waves, and current. Thanks to 4 different measurement systems such as inclinometers, accelerometers, pore pressure, and long term settlement data analysis was performed for structural assessment purposes. The analysis was focused on assessing the GBS structural response compared to the design values in order to check the integrity status of the structure, evaluate the amplification factor between GBS bottom and top slab, and determine natural frequencies and modal shapes of the GBS and its foundation.

For each recorded seismic event, acceleration data were analysed. Maximum recorded accelerations (0.25 m/s²) were around 15% of OBE (Operating Basis Earthquake, has a time of return of 475 years and will not cause any damages/interruption of normal working conditions) scenario, well below the design limits, but intense enough to evaluate the GBS structural response. The analysis of the acceleration data showed that the seismic events did not affect the position and foundation of the GBS. The analysis of the monitoring data during the actual events was well aligned with and allowed calibration of the theoretical modelling completed during the design phase. The value of the amplification factor between the GBS top and bottom slab was measured to be lower than the theoretical model prediction. Therefore, lower seismic loads were actually applied to the LNG tanks and main topside structures than would have been predicted by the model, a positive outcome for facility integrity.

The seismic structural assessment was completed with the evaluation of the data collected by the other measurement systems (pore pressure, inclinations and long term settlement). No anomalies were detected. The inclinometer data showed no rotations or distortion; the pore pressure data showed no changes in the subsoil under the GBS, and the long term settlement data showed no displacement of the GBS. These results were confirmed by a site survey carried out after each seismic event.

The analysis was extended also to the LNG tanks. Each LNG tank is equipped with a strain monitoring system. Technical evaluation of strain data allows the monitoring of the integrity status of each LNG tank and the assessment of the fatigue behavior of normal operations and exceptional events, such as seismic events. An analysis of the strain data was performed. No anomalous structural response of the LNG tanks was detected.

RELIABILITY

Notwithstanding the economic crisis that has affected gas consumption throughout Europe, and a global scenario where LNG has been mostly attracted by the Asian markets over the course of the last few years, the terminal throughput has surpassed 20 billion standard cubic meters of natural gas from startup through year end 2012, with 249 LNG carriers safely offloaded, resulting to be one of the busiest LNG receiving terminals on the European continent.

The Terminal is designed to provide a “nominal” send-out capacity of 21.9 million standard cubic meters a day (MSCM/d) over a calendar year (equivalent to 8 BSCM/year) with a high degree of reliability. To support this capability, equipment count, sizing and sparing are designed to enable short term “peaking” send-out capacity of 26.3 MSCM/d, i.e. 120% of nominal capacity. The major equipment installed on the Terminal (Turbines, LNG and Seawater pumps, Open Rack Vaporizers and BOG compressors), have either an installed or running spare to allow for individual equipment packages to be removed from service for maintenance with minimal impact on the “nominal” send-out. This “spare” equipment also provides the “peaking” capability to enable make-up of send-out volumes and to meet monthly volume delivery plans which may be impacted by periods of reduced send-out due to severe weather or process upsets. This “peaking” capability is a key factor in maintaining overall equipment, re-gasification and capacity reliability.

ALNG’s operations and technical organizations continue gaining experience and knowledge of the facility in managing long term reliability and undertaking maintenance planning. A ten-year major equipment and
facility maintenance and inspection plan has been developed to ensure consistent reliability in meeting ALNG’s long term commercial objectives. Major equipment servicing that limits peaking capability is typically scheduled between April and September, outside the winter security of supply period. In this way, the risk of experiencing LNG carrier offloading delays during the most critical winter period is reduced and lower gas demand in the summer period typically results in “available slots” for scheduling critical maintenance activities with minimal impact on revenue earning opportunities.

![Figure 9 – Regasification Reliability](image)

Throughout the third year of operation, the ALNG Terminal’s reliability has continued to improve with regasification reliability (defined as meeting the daily nomination) at 99.8% (from 98.9% in 2010), unscheduled equipment downtime at 0.3% (from 1.47% in 2010) and unplanned capacity loss at 3.9% (90% is weather related). The average daily send-out for 2012 was 16.3 MSCM/d and major equipment maintenance / inspection campaigns were accomplished with minimal impact on send-out plans.

Structured measures have been implemented in order to reduce unplanned shutdowns overtime, primarily with the Gas Turbine Generators and the distributed control system (DCS).

Regarding the GTGs, after a number of trips, upgrades to the control system were implemented in November-December 2010 in order to improve reliability of response during load variations. In particular, scan time for data acquisition was reduced, the delay time for the Low Low Lambda was increased, temperature and speed control loops were improved to align load step acceptance to actual engine capabilities, high exhaust temperature emergency shutdown and temperature control increment during load acceptance were modified, and the differential pressure transmitter across the combustion chamber fault delay was modified. Also, Load Shedding settings were aligned to GTG response time to peak power load. The GTGs continue to remain a critical system for overall terminal reliability, and further reliability enhancement initiatives are ongoing in conjunction with the manufacturer.

In June 2010 the Terminal began to experience problems with the DCS, such as blank screens for certain parts of the process, that ultimately leading to a process controlled shutdown. As corrective action, the DCS vendor completely re-loaded the software. ALNG made an analysis to fully understand the root causes of this event in order to prevent a recurrence. As part of the follow-up a cold eyes review provided constructive recommendations for how to improve the system and how it is maintained. Improvement actions were then pursued internally and with Yokogawa.

The duration of shutdown events has generally decreased, as well as the time to recover any production losses after shutdown events, thanks to the experience gained by the operating organization.

Each month, a 90-day forward send-out plan is agreed with users. These send-out plans are based upon the LNGC supply chain and account for several factors, including proposed LNGC arrival dates, anticipated LNG delivered volumes, available offloading slots, customer modulation requests and an underlying operating
philosophy which maximizes flexibility for potential weather events / delays. As was mentioned, the 2011 / 2012 winter weather season was quite challenging, with a 100 – year storm experienced in February 2012 (17-day duration). Tank inventory management practices have been very effective in maintaining planned send-out rates and minimizing weather impacts. Ability to meet some users’ requests for swinging nominations and some send-out flexibility has then proven to be extremely significant and highly appreciated by these same users. Higher sendout profiles during working days and lower profiles for the weekends have been recurring requests from customers and have been accommodated.

Severe weather delays can require large send-out rate swings in order to manage inventory levels.

ALNG will strive to maintain the excellent level of re-gasification reliability with additional focus on improved work planning and execution of planned campaigns for critical systems (GTGs and WHRU). Opportunities for further upgrades to the Terminal’s fender system may also provide improved reliability and additional efficiencies for LNGC offloadings during the winter season.

INTEGRITY MANAGEMENT PROGRAMS

The ALNG production facilities present a combination of complex concrete and steel structures, piping systems, pressure vessels and a gas pipeline. The Company developed and is executing comprehensive Integrity Management programs for all the above which address condition monitoring, inspection and testing of critical items with the aim of ensuring ongoing operational integrity during the operating life of the facilities.

As far as ALNG structures are concerned, the Integrity Management program is based both on a structural and geotechnical monitoring system and on a Risk Based Inspection (RBI) program addressed to monitor the adequacy of the corrosion protection system and to detect any other defects which may affect the integrity of ALNG structures.

Similar to the structures, the integrity of ALNG piping, pressure vessels and the pipeline is managed through a risk based approach in order to allow safe and reliable operation and optimal management of inspection related costs.

An overview of the key aspects of the ongoing structural monitoring and NDT plans for the concrete GBS, modularized LNG storage tanks, topsides structures and equipment as well as the pipeline is outlined below, with particular attention to:

- NDT plans associated with the concrete and steel structures, piping and pressure equipment, for the underwater and the above water portion of the structures.
- External and internal verifications of pipeline integrity.

The inspection program of the terminal’s concrete and steel structures, piping and pressure equipment, and pipeline is developed, implemented and maintained utilizing a risk based approach. The approach is aimed at safe and reliable operations through risk-prioritized inspection at an optimized cost. This approach is made up of various elements.

As a first step, a base-line NDT program was performed on the offshore and onshore facilities (piping and static equipment) and structures. The data collected in these campaigns have the aim of confirming that the facilities and the structures are free from construction defects as well as to provide base-line data. This information is collected in a dedicated computerized inspection management system (CIMS).

Consistent with the adopted risk based approach, base line inspection data is managed in conjunction with design and operating data in order to identify for each component the most likely damage / degradation mechanisms and resulting risks. The resulting risk is assessed through a qualitative approach by estimating the probability of failure range and the potential consequences. The results of these risk assessments are
used for the optimization of the inspection, monitoring and testing programs in order to reduce the impact of failure to As Low As Reasonably Practicable (ALARP).

Inspection and non-destructive testing activities are then planned and executed according to the program resulting from the risk assessment. Inspection data is recorded and analyzed to define maintenance / repair activities and to update the database and review the risk-based plan and program throughout the life of the terminal. Therefore, inspection planning, execution and evaluation are a continuous process where information and data from the inspection / maintenance / operation activities are fed back to planning, as represented in the flow diagram below.

For structures, the assessment of field inspection data is completed with the analysis of SGMS data in order to better evaluate possible failure mechanisms / degradation modes, and to affect, possibly reducing, the inspection frequencies. Hereinafter are summarized the main results collected so far for piping and pressure vessels, terminal structures, and pipeline.

**Figure 10 – Facilities Integrity Management Process for Inspections**

**Piping and pressure vessels.** Currently, the NDT base line campaign for terminal and metering station facilities has been completed, aimed at populating the data-base of the Computerized Inspection Management System. The NDT mainly consists in wall thickness measurements. Ultrasonic testing was used as the main technique, while for cryogenic lines (i.e., with insulation), radiographic analysis methods were used. Base line inspection campaigns were done on all pressure vessels and a portion of the pressure piping, selected based on a dimension and service condition criteria. All the inspection data was uploaded in the CIMS. Future steps include the preparation of optimized inspection programs based on the results of the risk assessments described earlier.

**Steel and concrete structures.** For concrete and steel structures, the base-line inspection campaign has two targets:

- To confirm the terminal structures are free from construction defects;
- To collect operational data in order to obtain static re-certification under Italian law (Legge 5.11.1971 n. 1086).

The base-line inspection plan for terminal steel and concrete structures has been structured on a 5 year timeline (from 2010 to 2014) due to the complexity and size of structures to be inspected. For above water structures, the inspection plan includes an annual general visual inspection and a series of more specific NDTs resulting either from the general examination or from stress considerations.
Those NDTs include close visual inspection, bolt inspections in order to check both the torque and the integrity status and weld inspections. Welded connections are examined through ACFM (Alternating Current Field Measurement) which allows detecting and sizing surface breaking flaws without cleaning the weld region down to bare metal.

For the underwater structures, the inspection program requires two underwater campaigns in the period 2010-2014. The first campaign was performed in 2010. Each survey consisted of a Level II and Level III survey. In particular, the Level II survey consists of general underwater visual inspection to detect the presence of any or all of the following:

- Excessive corrosion.
- Overloading.
- Scour, seafloor instability, etc.
- Fatigue damage detectable in a visual survey.
- Design or construction deficiencies.
- Presence of debris.
- Excessive marine growth.

The Level III survey includes close visual inspections and wall thickness measurements and is focused on certain areas that were preselected during the Level I survey (i.e., uncoated areas) and zones selected on the basis of the engineering evaluation of the areas which could be susceptible to structural damage, or areas where repeated inspections are desirable in order to monitor their integrity over time.

All underwater activities were carried out using a Remotely Operated Vehicle (ROV). Anode consumption measurements were also taken.

During the underwater campaign, a multibeam survey was carried out to check the status of the scour protection berm which consists of a volume of more than 14,000 m³ of rock installed around the perimeter of the GBS and the Mooring Dolphins in order to prevent the seabed from eroding around the GBS and the mooring dolphins.
Pipeline. In addition to routine surveillance / maintenance activities, pipeline integrity was measured internally (in-line inspection campaign) and externally (underwater survey). The in-line inspection was carried out with a Magnetic Flux Leakage (MFL) pig, able to detect internal and external defects due to fabrication, metallurgy or corrosion, while the underwater portion was performed by an ROV, moving along the seabed above the subsea pipeline. The underwater survey was aimed at checking:

- The cathodic protection level.
- The burial status and the position.

Both campaigns were performed in 2011. No defects were detected. Due to these results, the next campaigns are scheduled in 2016.
CONCLUSIONS

The Adriatic LNG terminal is a unique, state of the art facility with several industry firsts. The terminal was started up in September 2009 and was able to reach design throughput in only 3 months from when challenging cooldown operations commenced.

Relatively significant punchlist items were progressed post startup by the operating organization under severe work management restrictions, and were safely and mostly completed in 2010.

The first 3 years of full commercial operations were characterized by multiple weather events that tested reliability of LNG carriers berthing operations and ability of the operating organization to manage LNG offloading and inventories, and also tested fundamental design choices, such as the offshore location with no port infrastructure to protect its berth, and the enhanced offloading arms to accommodate the carriers under a variety of metocean conditions, with successful results.

The facilities were not affected by the earthquake that hit North-Eastern Italy in May-June 2012. The data from the GBS structural monitoring system and instrumentation installed on the LNG storage tanks were utilized to assess structural response of the structures to seismic events, with satisfactory results.

The Italian Government declared a status of Gas Emergency on several occasions, when extreme cold weather hit Europe in 2012, and when major gas importation routes to the country via pipelines were interrupted. Adriatic LNG confirmed the strategic role from security of supplies perspective that the Company committed to play when the Project was authorized by the Government, continuing to operate even under challenging circumstances and meeting requests for send-out flexibility from customers and the national grid.

Regasification reliability, unscheduled downtime, and unplanned capacity loss indicators have continued to improve over time, also thanks to specific reliability improvement initiatives with assistance of the quotaholders.

Effective Facilities Integrity Management with the aim of ensuring ongoing operational integrity during the operating life of the facilities is a key objective for the Company, and is being pursued by deploying a right-
sized system. Execution of extensive NDT plans for above and underwater structures, piping, pressure vessels and the pipeline is one of the most significant initiatives in this particular area.

Quotaholders support in specific areas such as SHEMS, risk management, equipment and systems reliability, has also been a key factor for the outstanding results obtained by the young ALNG organization.

The Adriatic LNG management goal to operate with zero injuries or occupational illnesses, zero spills or regulatory exceedances and no significant loss of containment, equipment damage or business loss is relentlessly being pursued with exceptional and improving result.

Figure 13 – An LNG carrier is Approaching the Adriatic LNG Terminal

REFERENCES

Mangia, C., “Offshore LNG receiving terminal meets most stringent regulatory requirements, makes efficient use of energy”, Hydrocarbon Processing, 2007