Montoir LNG Terminal Development: Matching European Gas Market needs by enhancing the maritime compatibility

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Presentation of Elengy

Elengy currently owns and operates the LNG terminals of Fos Tonkin, on the shores of the Mediterranean, and Montoir-de-Bretagne on France's Atlantic coast. It also operates the terminal of Fos Cavaou, owned by the Société du Terminal Méthanier de Fos Cavaou in which Elengy's share is over 70%.

Offering access to all LNG importers for the French and broader European markets, Elengy's terminals cater for vessels of all sizes and unload LNG from many countries around the world. It thus contributes to the security and competitiveness of LNG supplies to Europe. A subsidiary of GDF SUEZ, Elengy operates independently, under the supervision of the French Energy Regulation Commission (CRE). Its goals:

- To strengthen its position as a leading LNG terminal operator by providing safe, competitive and innovative solutions for its customers;
- To leverage its LNG expertise in order to contribute to new international projects.

I - Background

I - 1 Terminal history

Montoir LNG Terminal is located in France on the Atlantic coast. It has been built on the north bank of estuary river Loire and is laying on a surface of 73 hectares.

Since its start-up in 1980, Montoir terminal has received nearly 2500 cargos carried by 100 different ships and from 11 different LNG sources. The effective use rate of the Terminal during these 30 years is higher than 55%.

Terminal facilities consist in two berths for large ships and three tanks of 120 000 m^3 LNG each. Its nominal send-out capacity is 10 bcm per year.

Montoir LNG Terminal benefits from Elengy's 45+ years experience in operating LNG terminals.

Figure 1: Terminal general layout highlighting the ability to receive two LNG Carriers

I - 2 A Terminal with relevant features for 21st century NW European gas market

A large development potential: Montoir LNG terminal has a potential for development thanks to the large area where it is currently located in the Port of Nantes Saint Nazaire. Initial engineering studies and constructions were actually dealing with possible extensions and this explains this comfortable layout for development.

A positive local insertion: Montoir LNG terminal benefits from a positive local perception finding its roots in a long term local involvement of the terminal management. Regular contacts are developed with local authorities. Following a consistent strategy of long term sustainable integration, Montoir is also actively supporting non profit back to work organisations or environmental non governmental organisations. As a result, Montoir development is supported by the local interested parties.

A reliable maritime configuration: From a maritime point of view, access to Montoir presents some operational advantages:

- 54.4 m air draft
- 24/7 Access on slacks of tide with the assistance of Port pilots for any port maneuvers
- Good weather predictability

Figure 2: Port access overview

The terminal is also involved in a dynamic of constantly expanding its maritime compatibility since the end of the 90's. Montoir progressively switched from its initial situation with two dedicated LNG Vessels involved in an historical LNG chain between France and Algeria to the current configuration where approximately 40 different vessels, including Q-Flex since 2009, unload at the terminal each year.

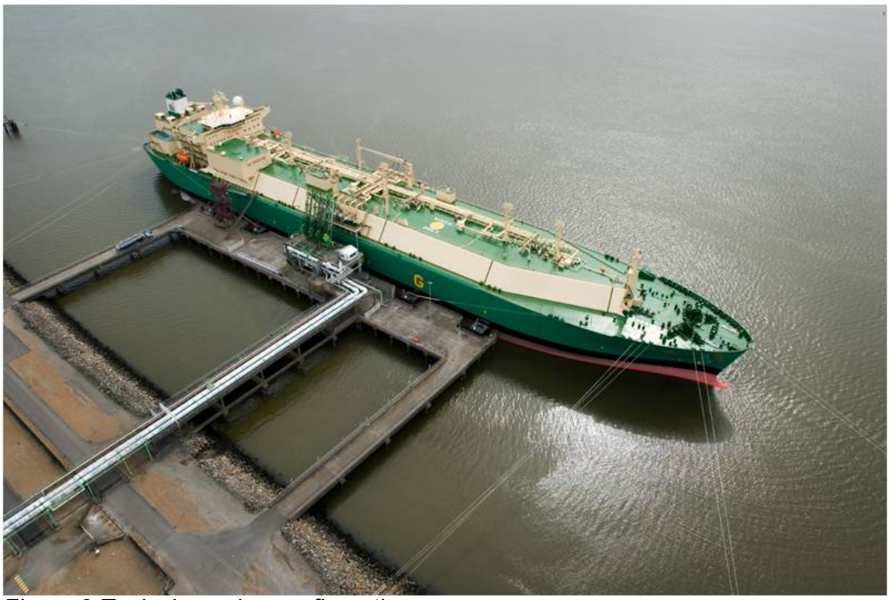

Figure 3:Typical mooring configuration

A dynamic hinterland: Montoir LNG Terminal is also at the crossroads of European gas routes. Montoir LNG deliveries allow a direct sendout to the PEG North marketplace which activity is growing significantly. From this marketplace, market players are in a central position between Northern and Southern Europe as illustrated below.

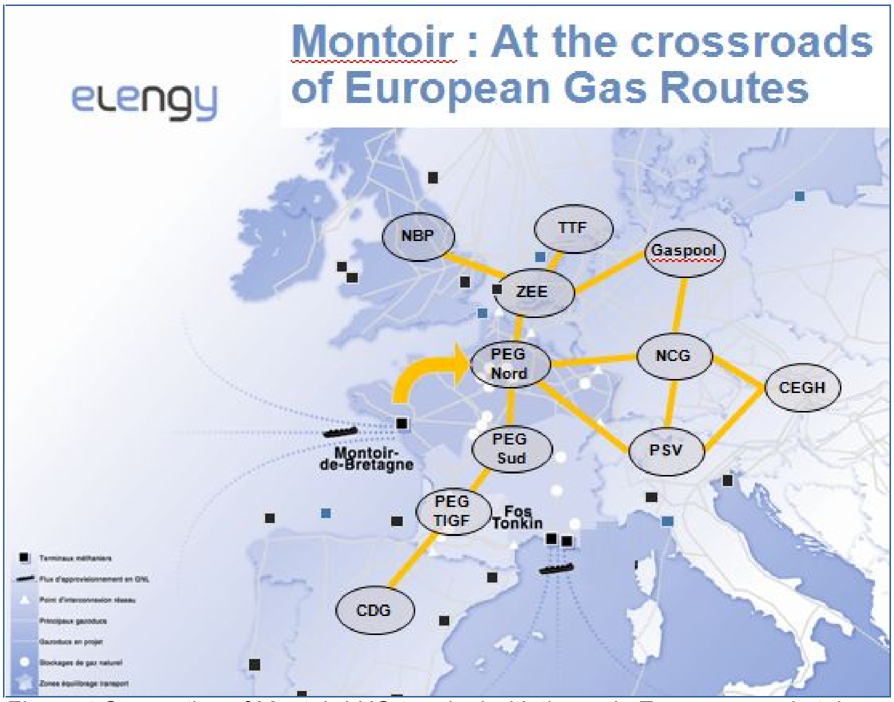

Figure 4:Connection of Montoir LNG terminal with the main European marketplaces

I - 3 An investment decision taken in 2007 based on market expectations

Based on the favorable context presented in the previous paragraphs, Elengy was convinced that there was an opportunity to expand Montoir LNG Terminal's operational life beyond 2021 up to 2035.

Starting from this conviction, a large technical and commercial assessment was carried out by Elengy, involving relevant stakeholders (Port Authority, local HSE Authorities):

On one hand, a set of technical assessments was initiated in order to evaluate, technically and financially, the scope of the works required by the life extension project. These studies are presented in the following paragraphs.

On the other hand, a market consultation was launched in 2006 to present the various expansion projects to the LNG market players. This transparent operation showed an important interest for Montoir as an entry point to European gas markets. This open season was concluded by a positive economic test, based on sufficient commitments from customers, to bring the life extension project to Final Investment Decision (FID).

Life extension project is designed for a total investment of more than 150 M€ with works between 2009 and 2013.

II - Montoir LNG Terminal's ambition: Reliability based on Elengy's know-how

II - 1 General objectives: Lifetime extension – Expansion of shipping compatibility – Expansion of the service features

The project initial functional specification indicates three different sets of objectives, consistent with a sound commercial offer for the market.

Life Extension: A full review of terminal major equipments shall be made and the project will include all necessary works to expand terminal nominal operation at its current capacity of 10 bcm/year till 2035 ;

Maritime expansion: The overall geometry of the terminal berths was designed in the late 70's in order to accommodate a strong increase in LNG tanker size. A reference tanker size of 300 000 m^3 LNG had been mentioned at that time. In this context, a detailed evaluation of each technical component of the maritime facilities shall be conducted to precisely identify any marginal adaptation that could be required to accommodate Q-Max LNG tankers. The project will include the required maritime works ;

Service expansion: The significant works included by the project should be considered as an opportunity to further develop the terminal services panel. This important project will allow Elengy to evaluate the various technical adjustments that could improve either the terminal reliability, its environmental impact or develop the terminal service features. The project will include the most relevant service development works.

II - 2 Specific Project Execution objectives: Safety first

The project has key project execution objectives:

Safety as a first priority: Safety always ranks first in any decision process. Safety awareness is the primary objective at each phase of the project: Elengy applies International Safety Rating System (ISRS7©) standards from the design of the technical solutions to the construction works on field.

Execution in compliance with the project budget: The whole commercial and economical relevance of the project is dependent on its budget compliance. Elengy has developed specific project control procedures in order to be able to detect and correct as early as possible any deviation from the budget target.

Execution in compliance with project planning: The commercial relevance of the project but also its insertion in a terminal in operation makes planning a highly sensitive issue. Therefore, project execution includes a frequent monitoring and a periodic re-estimation of the project planning in order to avoid or manage delays.

Quality insurance: Compliance of the technical works with the owner's specifications is controlled by Elengy's teams. Project workforce includes terminal operators and technical experts.

Service continuity: LNG deliveries were not reduced during the project. Therefore, the relationship between project teams and terminal staff was important. Furthermore, works schedule was regularly adjusted in connection with Elengy team in charge of the LNG Delivery Programme. For these two critical interfaces, a specific management methodology has been defined.

III - Focus on the preliminary technical review used to design the project framework

The project definition has been based on ageing studies carried out on every major facility of the terminal. The purpose of this paragraph is to highlight the technical challenges encountered during this assessment period and to put into perspectives the principal technical choices of Elengy.

III - 1 Tank technical review

Two major LNG tank containment systems coexist in Montoir:

- 2 membrane containment tanks with a 120 000 m^3 LNG storage capacity,
- 1 full containment 9% Ni tank with a 120 000 m^3 LNG storage capacity.

Figure 5:Internal view of a membrane containment tank

In both cases, the external tank is made of pre-stressed concrete, with a 90cm thickness at its base and 30cm on the dome. The three tanks are built on more than 100 foundations piles linked to the bedrock located 30m below ground level.

The scope of the tank expertise carried out in 2006 was to identify any mitigation to implement in order to extend tank life. The following 4 aspects were investigated:

- Concrete ageing,
- Pre-stressed cable corrosion,
- Overall mechanical resistance to an internal overpressure,
- Ageing of internal thermal insulation with a potential impact on external concrete integrity

In this context a material analysis on concrete and steel cables has been conducted for each tank. Technically, these investigations consist of:

- Visual inspection in order to identify any disorder
- Magnetic and electromagnetic thickness measures of reinforcement steel cables and their protection coating
- Drilling of concrete samples to precisely assess carbonation depth and chemical composition. It led to compression resistance evaluation and allowed microstructural analysis

This comprehensive expertise did not show any evolution of the concrete tank properties from its initial situation.

Regarding the thermal insulation system, thermal conductivity measures have been carried out on samples dating from terminal construction. These measures have been compared with infra-red thermography performed on-site. This study did not show any ageing process occurring on the insulation system.

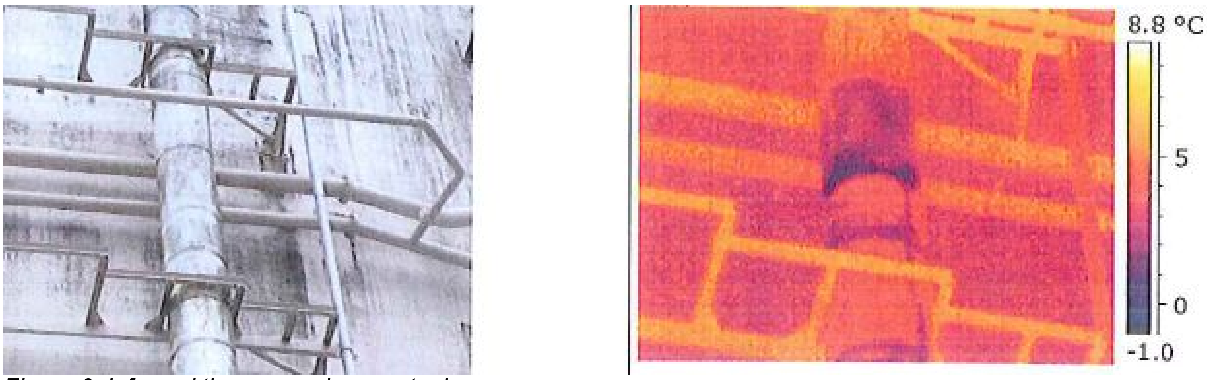

Figure 6: Infra red thermography on a tank

III - 2 Process expertise

Equipments and facilities are subject to a constant ageing process due to climatic oceanic conditions on site. Equipments located on tank domes, on berths and on racks supporting process pipelines are particularly exposed to these severe climatic conditions

Therefore, a detailed inspection of these facilities has been carried out in order to select critical equipments requiring to be replaced. This detailed inspection highlighted a more serious corrosion level on particular locations:

- pipe supporting systems located on the unloading and send-out lines
- metal frame supporting some platforms on top of tanks
- electric boxes and associated cables on tank domes and on berths
- Metal support structures of open rack vaporizers

Figure 7:Corrosion impact on a pipeline support system (before and after replacement)

Most of these facilities do not benefit from an easy accessibility and, for this reason, are not concerned by any preventive maintenance action. Hence, it is typically critical to include their inspection based replacement in any thorough analysis regarding lifetime extension.

III - 3 Maritime expertise

In order to ascertain the feasibility to receive Q-Max ships at the Terminal several studies were done on the nautical side of the Terminal.

These studies where:

- Compatibility with existing structure
- Compatibility with the overall port environment

III - 3 - a) Assessment of berth capabilities

The Montoir berths have the following architecture:

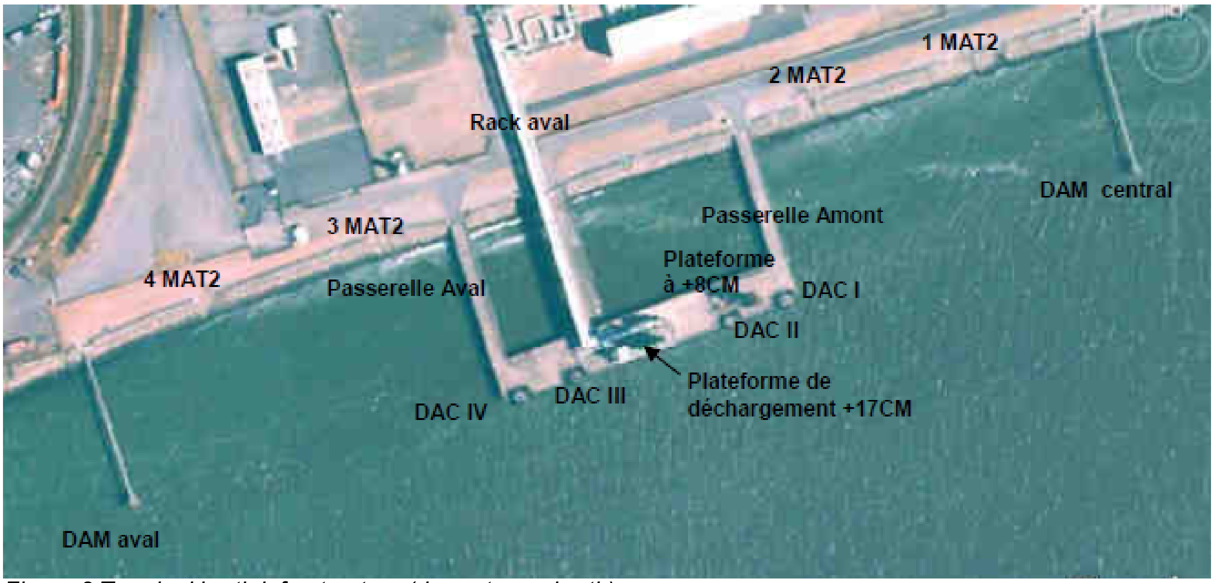

Figure 8:Terminal berth infrastructure (downstream berth)

Each berth comprises:

- 2 mooring dolphins (head and stern lines)
- 4 breasting dolphins (spring lines)
- 4 shore mooring points

Each dolphin is designed in a single and flexible tube. This particular aspect is important for the future developments of this note.

On the dolphins, thickness measurements were carried out at first in order to assess their remaining mechanical properties. The expertise concluded that Marine structures are practically intact thanks to the cathodic protection of the Terminal after more than 30 years.

It was however confirmed that existing structures were not able to bear the berthing impact of a Q-Max because of the close interaction between installed fenders and dolphins' technology.

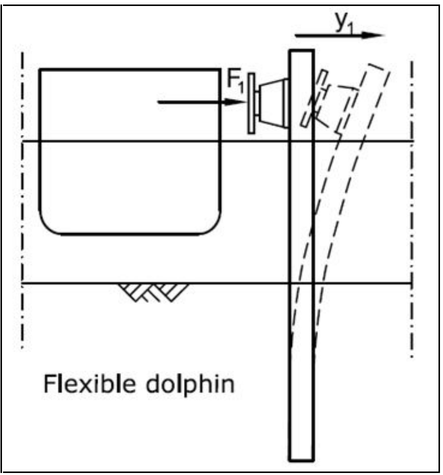

Figure 9:Principle of a flexible dolphin

It was then decided to study the possibilities to upgrade the berthing energy capabilities of the dolphins and associated fendering systems. By selecting a proper fendering system with sufficient energy capability and reaction adapted to the breasting dolphins. We concluded Q-Max could be received at Montoir with rather limited modifications on the Terminal berth.

In parallel, mooring studies were carried out for Q-Max ships in the Montoir environment. It resulted in the requirement to add a third hook for head and stern lines.

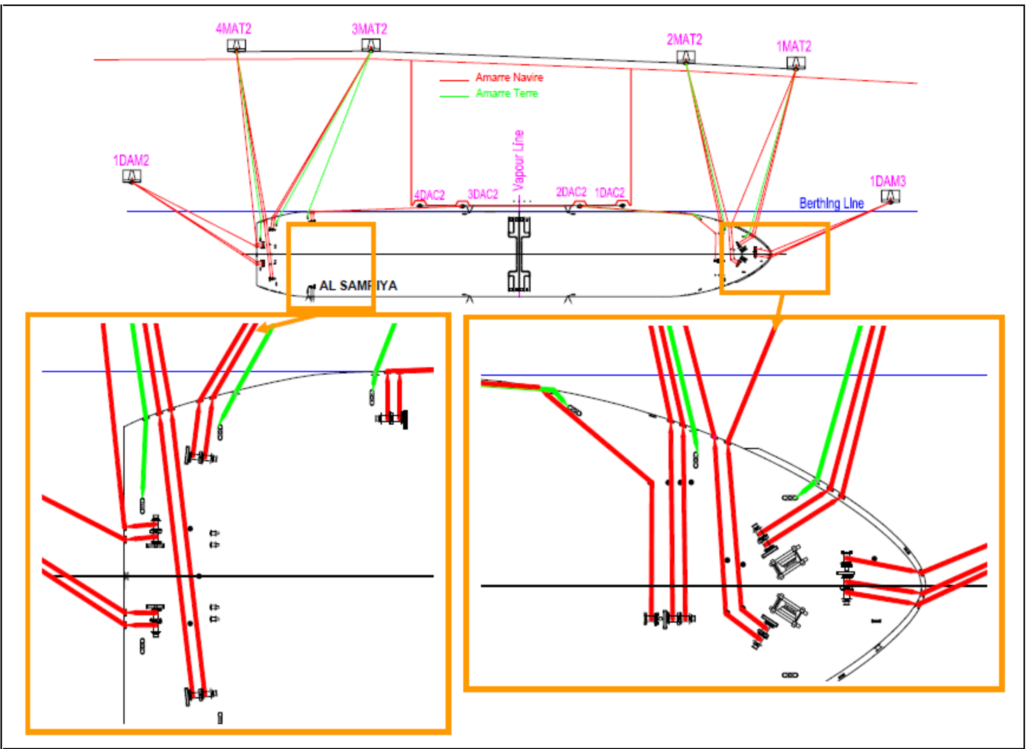

Figure 10:Description of the selected mooring configuration

In conclusion, Montoir berths appeared to have:

- A positive feedback on the ageing of marine structures
- Capability to receive Q-Max ships with minor modifications thanks to the original design of the Terminal

III - 3 - b) Assessment of Port environment:

Elengy has organized ship navigation simulations at the SPSA facility (Pilots Syndicate for the Atlantic, Brittany and Overseas simulator).

The objective of these simulations was to assess operational limits to be applied for normal berthing and unberthing of Q-Max LNG tanker at Montoir de Bretagne LNG berth n°2 and the required tug capacity.

Figure 11:Simulator view

Maneuvering behavior: Q-Max LNG carriers are very large ships with a breadth of 55m and total length of 345m. They generally have a relatively narrow hull shape. They have large exposed windage areas, due to their tanks, pipe work and other equipment mounted on the deck, which makes the vessel more significantly affected by the wind, when compared with conventional vessel.

Q-Max LNG vessels are fitted with two Diesel main engines, which give a more flexible maneuvering performance and good stern power than LNG carriers with steam engine. In addition, Q-Max have two main engines with twin propellers, which enhance the vessels's turning performance, in emergency, when one engine is set ahead, and the other astern.

The main maneuvering issue relating to Q-Max is their size and inertia, making it difficult and slow to maneuver using either its own effectors, or tug assistance.

A number of emergency scenarios were also considered to investigate the implications of a range of critical ship equipment malfunctions during maneuvers, such as rudder failure and blackout with loss of engine. These scenarios were selected to represent the most challenging, yet credible, emergency situations anticipated at the site.

Navigation simulation: The real time navigation simulation, which was run for this project, was conducted at SPSA in Nantes France and supervised by Elengy teams and Port Authority.

The simulator is characterized by an own-ship (assisted vessel) interacting with automatic tugs.

The bridge set-up for the assisted ship is installed on a simulator bridge, which provides a 360º visual system. By means of a view-selection panel the line of sight can be changed to any direction and the eye-point can be changed from bridge centre to starboard or port bridge wing.

For this study, the real time ship simulator was configured to provide a full representation of the River Loire estuary and Montoir de Bretagne LNG terminal on one hand, and of the the various approaches to the terminal and visual model of assisted ship and tugs on the other hand.

Personnel from Stasco Ship Management and QatarGas attended. Three senior pilots from Nantes – St Nazaire pilot station and a former LNG carrier Master undertook all of the simulation runs.

Figure 12: Navigation simulation

Met ocean conditions: In this study, the bathymetry of the river Loire and the immediate approaches to the berth were taken from recent survey information from the “Service Hydrographique et Océanographique de la Marine” (SHOM) and detailed bathymetry was taken from last updated survey from “Nantes – St-Nazaire” port bathymetric department for access fairway and basin nearby the berth n°2.

The wind conditions and gust effects (speed and direction) for each simulation were selected before each run, based on the maneuvering scenario. In most runs, the wind conditions were deliberately selected to represent the worst condition for the maneuvering ship.

The wave conditions were incorporated such that they were from the same direction as the wind and significant wave heights and periods were selected at the start of the run.

In the simulator the current speeds were scaled to achieve the current speed desired for each simulation. Indeed, current realism is a critical item in Montoir estuary configuration. The river was divided in several sectors, which were affected by the current (speed and direction) as per Pilots’ experience (see “Simulation run description” below).

Tugs: The maximum tug force deliverable by the tugs was varied according to the vessel water speed and the wave conditions. For these simulation runs, there were affected of an efficiency coefficient from 70 to 80%.

Simulation results: Each run was graded as successful, marginal or failed according to our internal evaluation criteria. Immediately after each simulation run, the Pilot in charge of the run was debriefed and his opinion on various aspects of the run was recorded.

A total of 34 simulation runs were undertaken for this study.

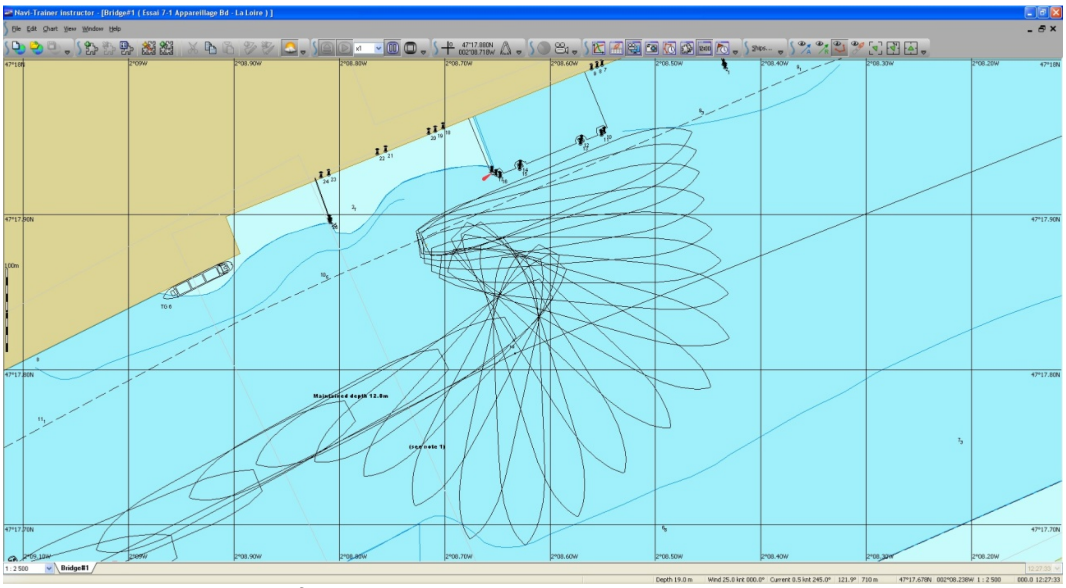

Figure 13:Maneuvering configuration

The initial agreed limiting conditions were found to be:

- Winds not more than 20 knots.
- Berthing portside to with 4 tugs (heading upstream)
- Departure with 4 tugs

It was also concluded that original design of the Port and Terminal were matching with the requirements for receiving a Q-Max type LNG Carrier.

III - 4 A particular opportunity: Implementing a synergy between the LNG terminal and a neighboring combined cycle gas turbine

As mentioned earlier, this project has also been considered as an opportunity to implement technical adjustments that could improve either the terminal reliability or its environmental impact. Regarding that matter, an original development has been identified which could at the same time significantly improve the terminal environmental impact reliability and increase the regasification reliability.

The principle of this synergy is simple: The LNG terminal process needs heat in order to regasify the LNG while the combined cycle power plant needs cold so as to cool down its turbine in the power generation process.

The symmetry between the energy needs of the two facilities is the base principle of the selected synergy. It has been practically implemented through the following development: Heated water from the power plant is injected at the inlet of the water transmission system used by the open rack vaporisers.

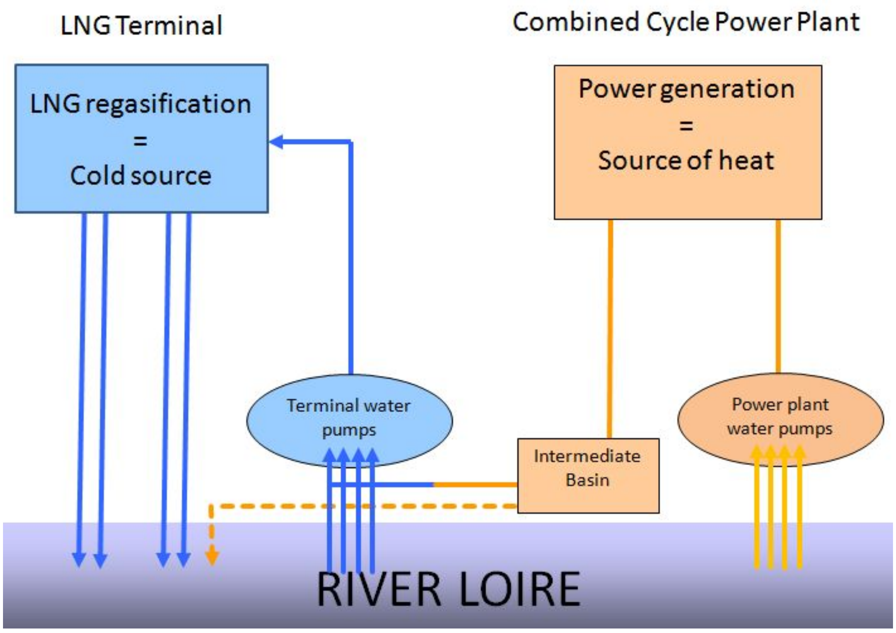

Figure 14:Principle of the synergy between the LNG Terminal and the power plant

IV - A project that was conducted without any significant impact on the service

IV - 1 Project organisation: Scheduling includes commercial aspects

The project, launched in 2008, has initiated significant works on site between 2009 and 2013. Even if the project activity was carried out on several key process areas, it was managed to maximize the separation between project works and day to day operations.

With this project execution methodology, the commercial regasification capacity was not affected by the project as illustrated on the graph below:

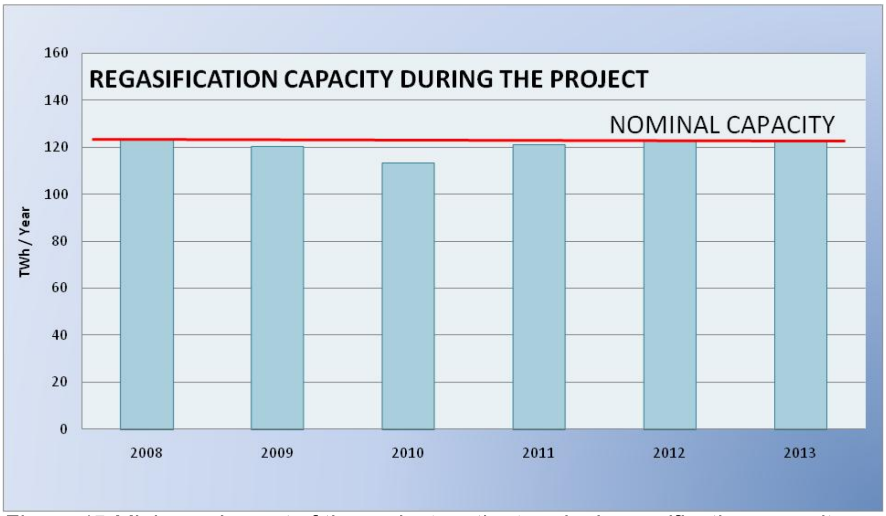

Figure 15:Minimum Impact of the project on the terminal regasification capacity

The capacity of the Terminal during the project has been maintained at 98% of its nominal value.

Service continuity was a requirement integrated by the project team at the initial scheduling stage. Any particular work on a part of the terminal has been scheduled ensuring that the overall regasification capacity could be maintained.

IV - 2 Systematic interaction with terminal operations

Conducting important works while the site remains in operation is a serious challenge. As described in the previous paragraph, the work scheduling process considered service continuity as a priority.

On a day to day basis, the interface between plant operation and project execution has been implemented by dedicating a specific team to that task. This multidisciplinary team was composed by terminal operators with the following specific competencies:

- Electrical engineering
- Mechanical engineering
- Instrumentation
- Terminal Operation

The experience and know-how of this team enabled a strict coordination between construction works, ships unloading and send-out requirements. Moreover, its contribution on the safety aspects was significant since the terminal operation was not interrupted and some works were conducted in safety sensitive areas.

V - Focus on works illustrating the technical diversity of the project

V - 1 Focus on works conducted on tanks

Tank painting was totally removed before carrying out new tank painting work.

Figure 16:Tank overview before painting works

The works carried out on the tanks led to a full refurbishment of the insulation and of the slatted floors on the dome.

Figure 17:Typical works carried out on the dome

Key process regulation valves have been replaced. Pipe supporting systems were also totally refurbished.

Figure 18:Valve replacement on the top of a tank

Lifting works on the dome of each tank involved one of the largest crane in Europe. This crane is presented below, lifting the new overhead bridge crane that have bee n installed on top of a tank.

Figure 19: Heavy lifting works on an LNG tank

V - 2 Focus on process works

The key process cryogenic valves have been replaced on the line between the berths and the LNG tanks. The sequence presented below presents the type of works conducted to prepare the removal of the existing valve, the situation before the installation of the new valve and the final situation.

Figure 20:Typical works including cryogenic valves replacement

The whole 6.6 kV power transmission network has been replaced with particular protection in sensitive locations such as roads or racks crossings structures.

Figure 21: 6.6 kV cables replacement

Works also have been carried out in order to fully replace the supporting structures of the open rack vaporizers.

Figure 22: Typical works on ORV's supporting structures

V - 3 Focus on marine works

Based on nautical and structural assessments, decision was taken to upgrade the Montoir downstream berth. Elengy decided to take this opportunity to expand the lifetime of the marine equipment and increase the strength and standard of interface equipment particularly by adding berth monitoring systems which are now well proven technologies.

However, the position of the equipments has not been changed as overall geometry of the berth was perfectly fitting the Q-Max dimensions and river Loire requirements.

V - 3 - a) Fenders and associated piles

The initial concept to implement the required adaptation was to fully replace the head of each dolphin pile and to include a new fender and a new pile access ladder.

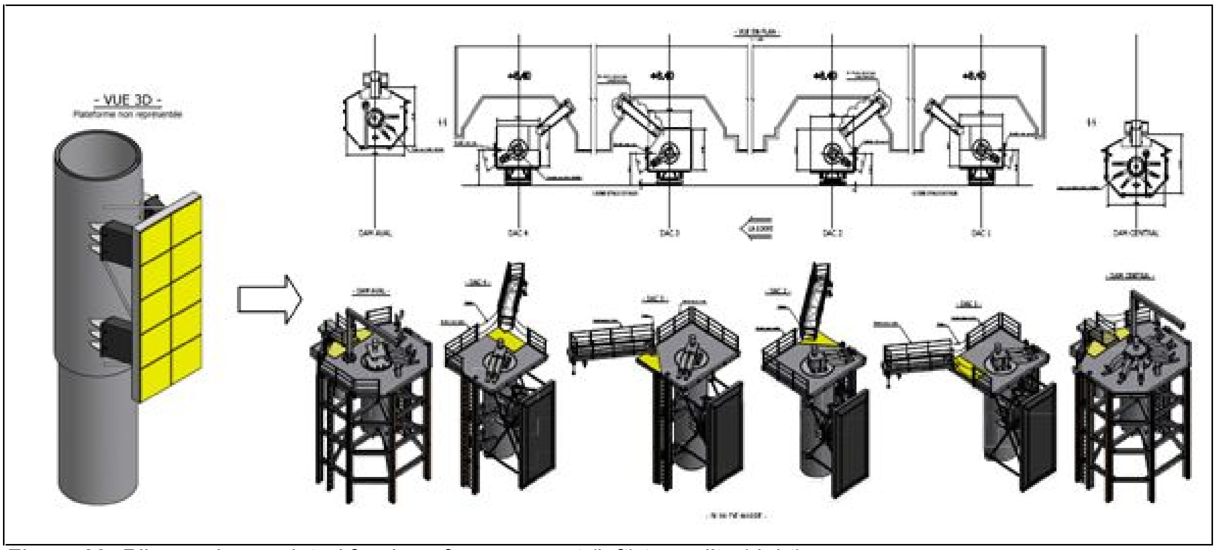

Figure 23: Piles and associated fenders, from concept (left) to reality (right)

This engineering concept was implemented through the following works sequence:

Figure 24: The existing pile is cut at its top

Figure 25: For each pile, a prefabricated fender module pile head is installed and commissioned

V - 3 - b) Mooring points and hooks

The other kind of major works conducted on the maritime side consisted of the renewal of the hooks: Safe Working Load has been increased to 150 Tons per hook. This required the building of new concrete foundations for each mooring point.

For stern and head lines, one additional hook was added, leading to a typical Q-Max mooring pattern of 3442 forward and aft from outside to inside including shore lines (Q-Flex are moored 2442).

This work the mooring points was also an opportunity to reshape the rock slope on which mooring lines usually lay down.

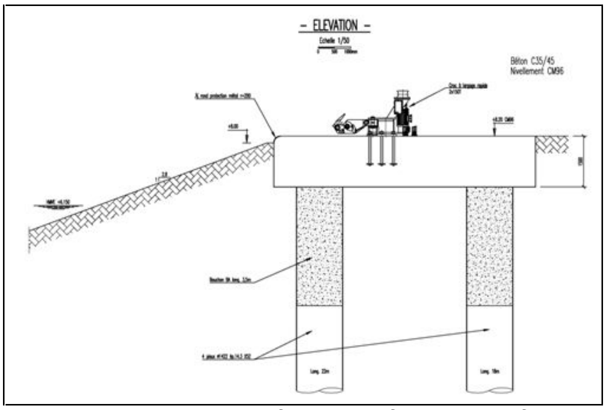

Figure 26: Initial design of concrete foundations for each hook platform

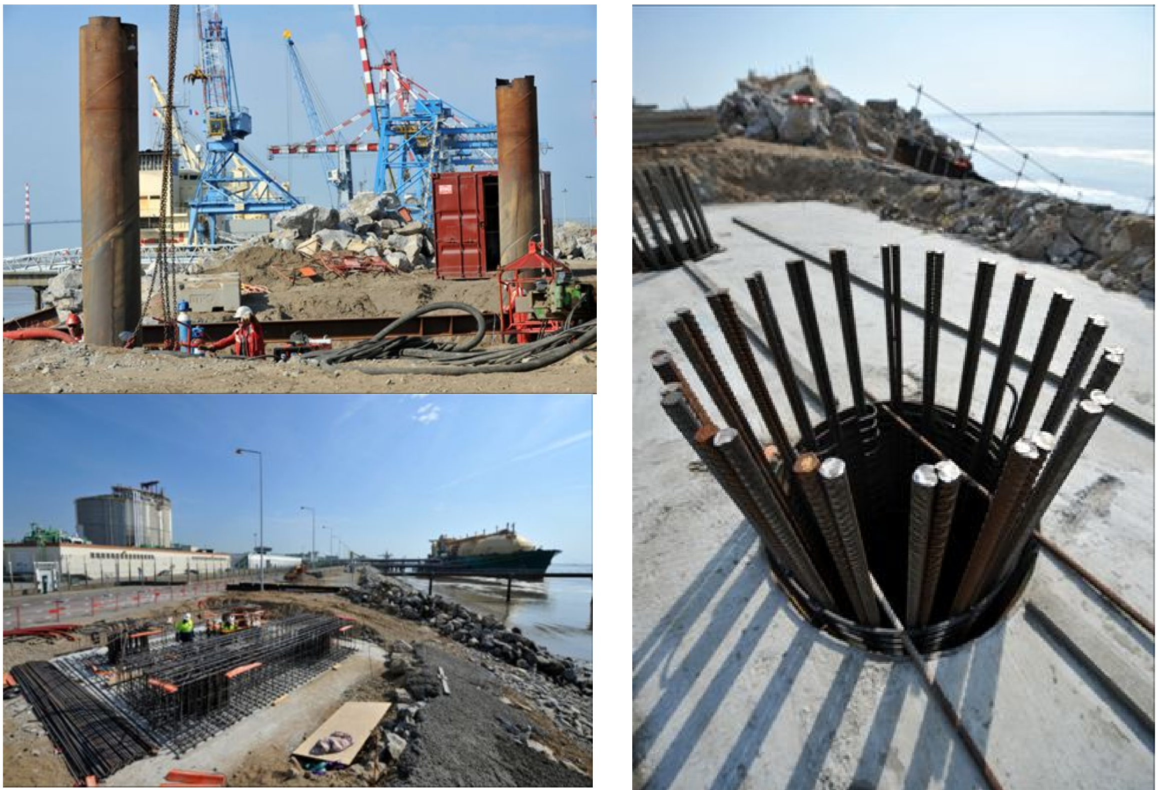

Figure 27: Excavation and pile construction

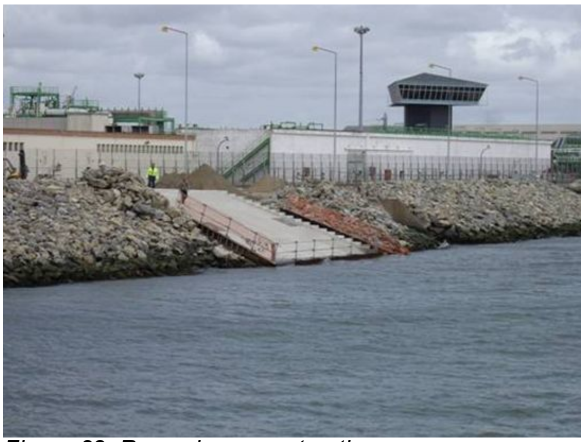

Figure 28: Rope slope construction

Figure 29: Final hook installation

V - 4 Focus on the LNG terminal / power plant synergy

The implementation of the synergy between the terminal and the power plant essentially consisted of major water piping works in order to connect both facilities

Figure 30: Synergy water pipes (from terminal)

Figure 31: Synergy water pipes (from power plant)

VI - Results

VI - 1 General results

Extension in time: The project implementation has led to a significant commercial growth of customers interest for Montoir LNG Terminal. Montoir LNG Terminal is now offering its regasification services to the market with a strong customer base until 2035. This is quantified by the following charts which represent the level of subscription in Montoir before (end of 2007) and after the project (situation as of January 2012) implementation:

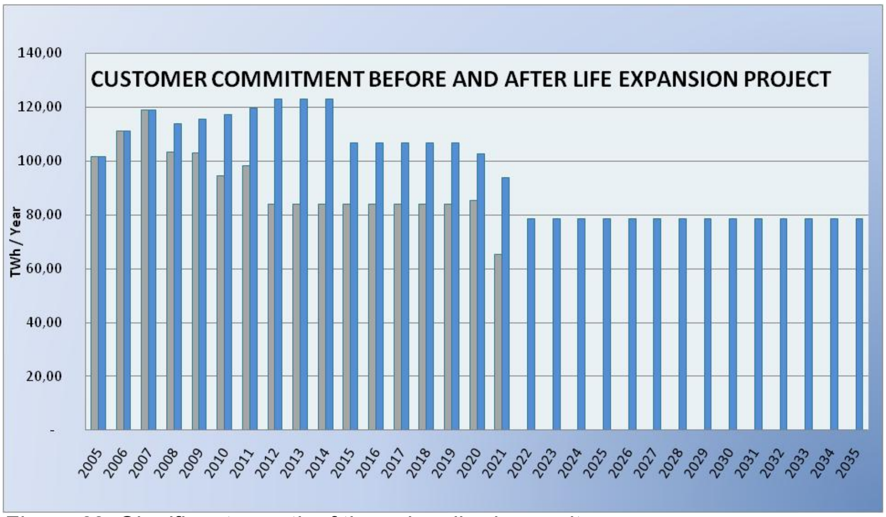

Figure 32: Significant growth of the subscribed capacity

This project also strengthened the interest of European market players for Montoir LNG Terminal with a constant increase of our customers portfolio:

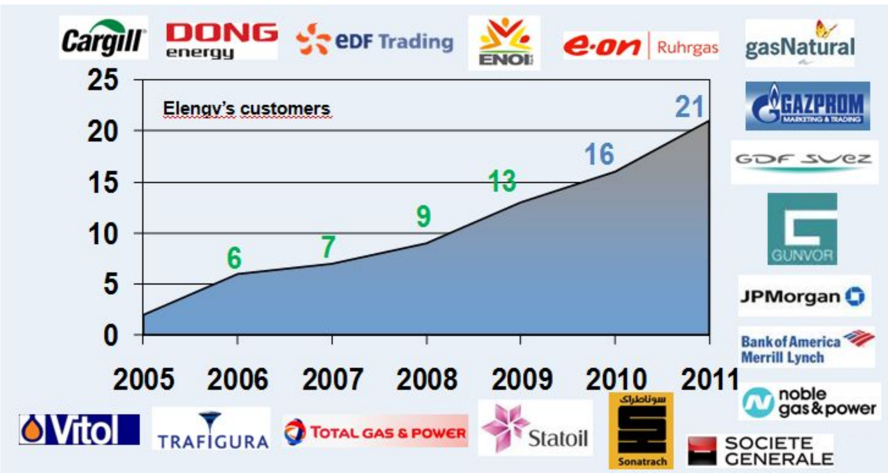

Figure 33: Development of the customers' portfolio

Expansion of shipping compatibility: The works on the downstream jetty of the Terminal in 2011 led to the official announcement of Montoir being "Q-Max ready" at the beginning of the fall 2011.

Expansion of some service features: The synergy between the LNG Terminal and the Combined Cycle Power Plant started up at the end of 2011. Its efficiency in stabilizing the water temperature at the inlet of the Open Rack Vaporisers water transmission facilities has increased the reliability of the regasification facilities. This has enabled potential gas terminal consumption savings thereby reducing the effective gas in kind rate applied to unloaded LNG quantities.

VI - 2 Specific project results

The project has been conducted with a high level of safety. The project safety record 2008-2011 gives a clear perception of this safety achievement, for a total manhours of more than 700 000 h:

- LTI Rate < 5
- Gravity Rate < 0.05

This safety achievement has been attained while being in compliance with the initial planning and budget.

Regarding service continuity, the terminal commercial capacity was maintained at 98% of its nominal value during the 6 years of the project and not a single contractual LNG delivery has been impacted by the project.

VII - Conclusion

This project has been particularly challenging as it has been conducted with no significant impact on the commercial service provided by the terminal This project has also been a collective challenge bringing together a wide diversity of experts involved in the different phases of the project, from the evaluation of its opportunity to the effective operation of the facility.

Adapt an infrastructure to market expectations is actually a permanent process. Elengy commercial and technical staff will keep offering to the market players innovative solutions to meet their ambitions on NW Europe gas markets.

This project was a significant step in making Montoir LNG Terminal a reference in service competitiveness for the next 25 years.

From this strong basis, Elengy people are keen to address the numerous issues which customers have shown interest for with the constant objective to propose new innovative and competitive solutions:

- Enhance the arbitrage flexibility by developing LNG storage capacity in order to limit interactions between customers, enabling them to implement specific market strategy;
- Developing small scale logistics by developing alternative means to set up LNG logistics at a smaller scale;
- Identify new environmental innovations to further reduce the environmental impact of the LNG Terminal.

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