# Reducing the catastrophe risk in coastal areas: risk management at FSRU terminals

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***Abstract:*** *Today, coastal areas are among the most densely populated and busiest places in the world, with an extremely important economic and social value. With those areas being very intensely exploited, there is a strong possibility of different accidents and catastrophes occurring. Therefore, it is a matter of great importance to implement timely and quality measures to minimize the risk of negative consequences. This research explores the theories of coastal area management and risk management, while focusing on the synthesis of both of them on FSRU terminals. Given the fact that this special type of LNG terminals is becoming more and more present in the coastal areas of the world, this paper implements analysed theories and proposes risk minimising and safety measures for reducing the catastrophe risk with FSFRU terminals and thus contributing to the preservation of the coastal area.*

***Keywords****: COASTAL AREA MANAGEMENT, LNG TANKER, FSRU TERMINAL, RISK MANAGEMENT, SAFETY*

## *1. Introduction*

This research focuses on risk analysis, risk management techniques and methods to reduce risks to acceptable levels in an extremely rich but also sensitive coastal area. It should be appreciated at the outset that risk can never completely disappear, it always exists, but it is possible to reduce it and reduce it to the level of acceptable risk [1, 2]. What is the acceptable level of risk depends on the situation and various factors, and this is one of the items that need to be defined during the risk management process. The entire risk management process can be divided into two main segments. The first is risk assessment, and the second is action to reduce it.

As there are many possible scenarios for various ventures and projects in the coastal area, the number of potential disaster risk reduction measures is exponentially higher. Each individual project that begins carries certain risks, and therefore for each of them it is necessary to develop and apply a system of disaster risk reduction measures, and apply theories of coastal zone management and risk management [3]. A large number of countries use FSRU terminals (Floating Storage and Regasification Unit) for transhipment of liquefied natural gas and one of these countries is the Republic of Croatia, where preparations are currently underway for the construction of such a plant in Omišalj on the island of Krk [4]. Ship-to-ship transfer, which is one of FSRU transhipment methods is shown on Figure 1.

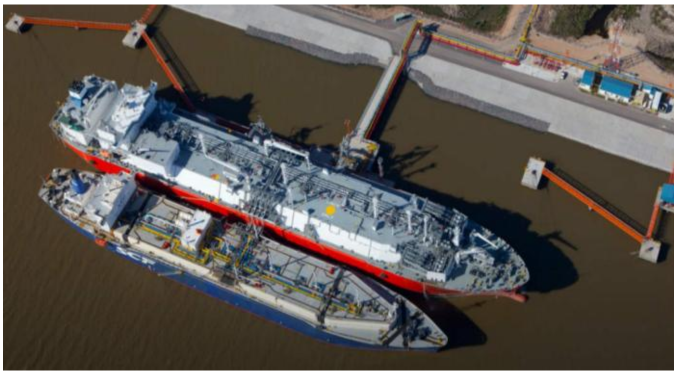

***Fig.1*** *Ship-to-ship transfer. Source: MFAME, Excelerate Energy: All Set for 1000th Ship-to-Ship Transfer of LNG Celebration, 05.08.2016., https://mfame.guru/excelerate-energy-set-1000th-ship-ship-transfer-lng-celebration/ (27.07.2020.)*

It is important to note at the outset that the floating terminal for the import of liquefied natural gas is actually a ship connected to the onshore pipeline through which natural gas is further transported to end consumers [5]. Once the liquefied natural gas is unloaded at the FSRU terminal, a regasification process needs to begin before the natural gas can be sent further to the onshore pipeline network to supply consumers. The regasification system can be considered the main functional system of each FSRU terminal, since it is in this system that the conversion of gas from liquid to gaseous state takes place [6]. Figure 2 shows a schematic of the regasification process at the FSRU terminal.

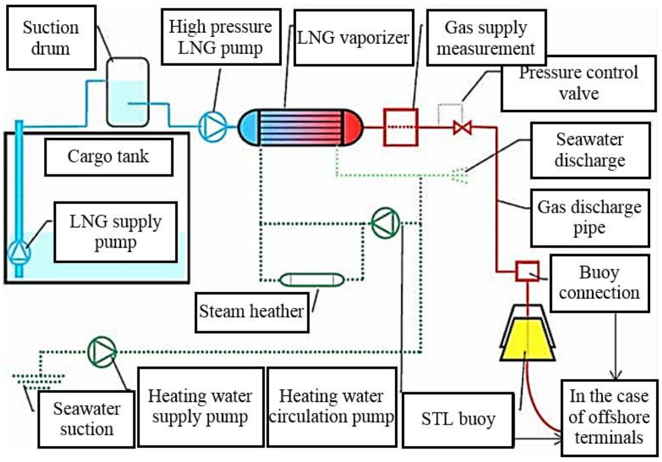


***Fig.2*** *Schematic of the regasification process. Source: authors on the basis of Janssens, P., Energy Bridge: The World's First LNG Offshore Solution, Gastech, Bilbao, Spain, 2005.*

When conducting a risk assessment related to the import of liquefied natural gas through the FSRU terminal, the analyses must include the FSRU ship, incoming LNG tankers, other coastal infrastructure and the terminal, location and local meteorological and oceanographic conditions, traffic in the waters and the surrounding area.

Four categories of factors influence risk assessment [7]:

- location, specific local conditions, LNG imports, importance for the region
- potential threats, potential accidents, possible accidents, critical coastal infrastructure and FSRU ship, incoming LNG tankers
- risk management objectives, identification of consequences to be avoided (e.g. injuries or damage to property), importance of LNG supply
- possibilities of protective mechanisms, safety measures, warning and alarm systems, reaction measures in case of accident

These categories must be taken into account when determining whether the implemented safety measures can successfully achieve the desired level of risk management for a particular project in a particular area. Hazardous projects such as liquefied natural gas imports should be regularly re-evaluated, in order to reassess the adequacy of the safeguards applied because conditions may change frequently. For example, changes in the context of facilities, coastal infrastructure, the emergence of new threats, changes in risk management objectives and many others.

## *2. Methodology of risk assessment*

When joining each project, some benefit is expected from it for a certain cost. However, each project carries with it certain risks, and it is often necessary to implement certain risk reduction measures, which also represents additional costs. It is for this reason that this analysis is done, which determines the methods that can be used to keep the project profitable in the end. In this way, a balance is sought between the costs caused by the implementation of risk reduction measures and the residual level of risk. As pointed out earlier, the risk can never be completely eliminated, but only reduced to an acceptable level, and this is exactly what this method seeks to achieve, taking into account cost-effectiveness and potential benefits. As part of this method, the so-called cost-benefit balance is often used to determine the balance between costs and benefits, the ALARP principle. This principle is based on reducing the risk as much as reasonably possible by rational use of available resources. Therefore, if the implementation of some measures would slightly reduce the risk given the high costs of the measures, it is concluded that the implementation of such measures is not justified. Conversely, if the risk were significantly reduced for a reasonable cost of measures, enforcement is justified. From this it can be concluded that for the costs of implementing risk reduction measures and the risk reduction itself, it is desirable to be proportional in size. The ALARP principle is often displayed graphically, with three different fields representing risk levels. Figure 3 provides a pictorial representation of this principle.

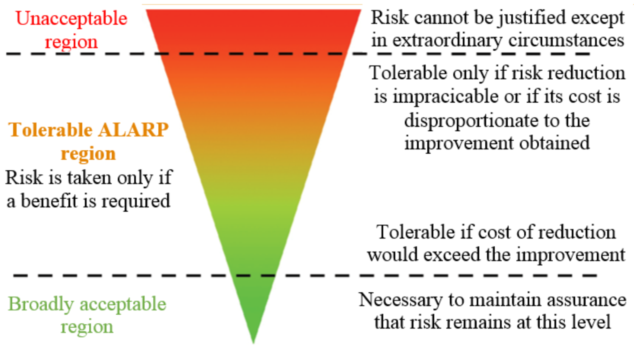


***Fig.3*** *Scheme of ALARP (As Low As Reasonably Practicable) system.*

The uppermost field represents an unacceptable risk, and it is mandatory to implement risk mitigation measures in order to reduce it to an acceptable level. The middle field represents an acceptable risk and the implementation of measures is not necessarily necessary, but it is desirable if an additional significant risk reduction would be achieved for a reasonable cost. The lower field represents a negligible risk that is so low that it is insignificant and can be ignored. Cost-benefit analysis together with the ALARP principle is almost always used when planning all projects in coastal areas.

The context of the FSRU facility such as location, micro location, specific local conditions, meteorological and oceanographic conditions, and desired cargo operations must be identified for risk assessment. Information that must be taken into account are:

- neighbouring surrounding area: distance from other port areas and facilities, distance from residential, commercial, industrial facilities, or other infrastructures such as tunnels, bridges, etc., as well as distance from regular traffic lines and flows
- prevailing weather conditions: wind direction and speed, possibility of particularly dangerous weather conditions such as hurricane or hurricane wind, sea currents, wave height, seismic activity, type of sea bottom, proximity of river estuaries, possibility of ice, etc.
- cargo operations: size and design of the FSRU ship, expected frequency of delivery, size of tanks, regasification capacity, seasonal needs for LNG, required quantity of supply

In the process of identifying potential hazards and threats to the FSRU ship and the surrounding area, it is necessary to take into account "unexpected" accidents, but also the possibility of intentionally caused accidents such as in the case of terrorist attacks [8]. Potential accident scenarios include: leakage from tanks or pipelines, rupture of tanks or pipelines, collision with an incoming LNG tanker, oil spill due to damage to the hull, accidents with ballast system, shipboard accidents, fires, explosions, interruption due to significant worsening of weather conditions, danger of terrorist attacks, robberies, kidnappings, etc. It is important to emphasize that in case of operation of FSRU ship as a receiving LNG terminal, there is no danger of pollution of the marine environment with ballast water, since LNG tankers arrive with full cargo and without ballast. As they discharge the cargo, they take ballast from the local area, so there is actually no discharge of ballast water into the local waters.

## *3. Risk management objectives*

This phase involves determining the objectives of risk management and the level of severity of the consequences of accidents during LNG operations, including potential property damage, potential injuries, potential damage to public safety, etc. Setting goals is done in close cooperation with owners and managers, experts and scientists. The task of this step is actually to determine the acceptable risk, i.e. the extent to which it is acceptable to perform a process given the severity of the consequence that is potentially possible. It is impossible to reduce the risk to zero, but it is possible to reduce it to the extent that it is acceptable for a certain project and a certain area.

It is common for the following important factors to be taken into account when setting risk management objectives [9]:

- consequences in the event of a collision with an LNG ship
- consequences in case of spillage of LNG into the sea
- hazards caused by the spillage of LNG into the sea (damage to the environment, risk of fire and explosion, danger to the health of human, animal and plant organisms)
- hazards arising from spills from propellant tanks into the sea
- acceptable duration of the interruption of the FSRU ship
- speed of resumption of operation of the FSRU ship after a temporary interruption of operation
- consequences in case of operations' termination of the FSRU

## *4. Protective and safety measures to reduce risk*

This phase includes the identification of all safeguard operations to reduce potential risks and the safety and security measures of the FSRU ship and the surrounding terminal area. The general items covered by the risk mitigation safeguards is listed here, and the next chapters will describe in more detail the specific implementation of some of safety and security measures on FSRU ships [9]. Thus, safeguards that mitigate potential risks on FSRU ships include:

- safety measures for gas supply systems, pipelines, tanks
- regasification and distribution
- availability of medical, fire, police services and SAR services
- availability of a sufficient number of adequate tugs
- warning and alarm systems
- the possibility of rapid, efficient cessation of cargo operations
- safety aspects of FSRU ship design (double hull, fireproof, etc.)
- safety distance from other port areas and facilities, residential, commercial, industrial facilities and the like
- pollution prevent measures in the event of an LNG spill
- measures in case of fire, explosion
- measures in the event of a collision with an LNG ship on arrival
- measures for termination and commencement of cargo operations
- measures of reaction in case of war or siege
- evacuation plan
- security systems of the FSRU ship and the surrounding area of the terminal (protective fences, security guards, video, etc.)

## *5. Monitoring, evaluation and modification of measures*

Once safety and security measures have been in place, all for the purpose of mitigating risks, their effects need to be regularly monitored and evaluated during their implementation. It is necessary to evaluate their success in maintaining pre-defined risk management objectives, and to react if it is concluded that there is still room for improvement of the system. It is also important to regularly update and modify the existing risk management system, as there may be a change of context in terms of changing delivery volumes, construction of new facilities near the terminal, changing requirements related to international conventions, etc. Regular evaluations of the existing system and the application of new, updated safety and security measures increase the safety of people, property and the environment, and reduce risk, which is exactly what it aims to achieve.

## 6. Risk reduction measures

Regarding the system of measures to reduce the risk of accidents and catastrophes during the operation of a floating terminal for the import of liquefied natural gas (Figure 4 shows an example of an LNG spill), as well as the general protection of the terminal and the surrounding area, three main components are distinguished: safety, security and corrective measures in case of an accident. These measures will be described and explained in more details. Here, it is important to mention conventions and regulations that apply to this type of ship, and which actually serve as a basis for good practice in achieving security and protection of FSRU terminals.

***Fig.4*** *An example of an LNG spill. Source: Hine, L., MOL outlines lessons learned from LNG ship cargo release, 21.07.2016.*

FSRU terminals are adapted to special local conditions and legal regulations, and are subject to the national standards of the country in whose territory the exploitation takes place [10]. It is important to note once again that FSRU ships are subject to all the classic classification requirements for ships dealing with the cargo of liquefied natural gas. Therefore, FSRU ships, just like conventional LNG ships, must comply with the following conventions, codes and regulations of the International Maritime Organization (IMO):

- International Convention for the Safety of Life at Sea (SOLAS)
- International Convention for the Prevention of Pollution from Ships (MARPOL)
- International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC)
- International Ship and Port Facility Security Code (ISPS)
- International Safety Management Code (ISM)
- International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)

In addition to the above conventions, it is clear that FSRU ships must comply with all other conventions in the maritime world. Furthermore, it is necessary to have valid certificates and documents in accordance with these conventions, and to meet all appropriate safety requirements prescribed by classification societies, flag state and the state in which the terminal is operated. In addition, these ships are required to comply with regulations related to the construction and equipment of ships performing regasification processes (Guide for Building and Classing LNG Regasification Vessels) and special instructions for LNG ships issued by the Society of International Gas Tanker and Terminal Operators (SIGTTO) [11]. Of course, in terms of ship construction, FSRU ships, as well as all new tankers being built today, must meet the standards of double hull construction, which is one of the most important safety measures to prevent accidents and catastrophes [11].

## 7. Safety measures

The term safety of the FSRU terminal refers to the day-to-day operations performed on it, and they can be related to cargo and cargo operations or any other area such as mooring or unmooring. Emphasis was placed on their proper execution and implementation of precautionary measures, as well as reaction measures in case of potential accidents during the execution of these operations. Several standardized safety systems are used, which are in fact the most common for all types of LNG ships, and their primary goal is to increase the safety of terminals, crew, property and the environment, and accordingly, reduce the risk of accidents and disasters.

### *ESD system*

An emergency shutdown system (ESD) is a system that has the important task of stopping all cargo processes active at the terminal in the event of an emergency. The system must therefore include all parts of the process at the terminal, namely: FSRU ship, LNG ship reloading cargo, tugs that must be on standby to access and tow the ship to a safe distance from the terminal in time and the onshore pipeline infrastructure and safety valves. Since this system is mainly used during cargo transhipment operations, in order to be functional, the system must be synchronized with the land infrastructure and other ship with which the transhipment is performed. After activating the system, the automatic shutdown of cargo pumps and compressors begins and certain safety valves are closed by the system. Also, in many strategically placed locations on the terminal, switches for manual activation of the system can be found, however, the main purpose of the system is that it is activated independently and automatically in certain emergency situations, thus preventing potential negative consequences. Some of the activation factors of the system are: exceeding the limit values of pressures in cargo tanks, land and ship pipelines or pumps, fire detection on FSRU ship, LNG ship reloading cargo or anywhere else in the terminal area, interruption of synchronization with other ship or land infrastructure and power outage. Before starting the process of reloading cargo from the LNG ship to the terminal, the entire system undergoes a thorough check to determine the state of readiness, after which transhipment operations can begin after it is clearly established that the synchronization of all parts is successful and the system is in standby mode.

### *HIPPS system*

The High Integrity Pressure Protection System (HIPPS) system is responsible for preventing excessive pressures in any part of the operating system during liquefied natural gas cargo operations [10]. The basic mode of operation of the system is to eliminate the source of overpressure by closing the predefined safety valves, shutting off the pumps or acting preventively by opening the vents before excessive pressures occur and rise above the maximum allowable values, thus preventing potential accidents. It usually works in combination with the aforementioned ESD system, and is activated as one of the safety factors of the system.

### *Pressure control and exhaust valve system*

The system has an important function of optimizing the pressures in the tanks and pipelines of the FSRU terminal in case of exceeding the previously set limit values, with the aim of safety of the terminal and its surroundings [11]. The system determines the minimum and maximum allowable pressure values, and in case of increase above the upper limit value, gas is released through vent valves and pressure is reduced, while in case of decrease below the lower limit value, additional gas enters and pressure increase occurs. This prevents potential damage to tanks and pipelines due to too high or too low pressures within the system. The system works by having the valve of each tank connected to its vent mast. In addition, each tank is connected to a main vent tank in which evaporated gas is collected before being discharged through the main vent mast, which is usually located somewhere on the bow of the FSRU ship [10]. As a flammable atmosphere is created when the gas comes out of the vents when the gas comes into contact with oxygen from the air, it is necessary to constantly treat the vents with nitrogen, which creates an inert or non-flammable atmosphere. At the bottom of each vent mast there is a valve that regulates the release of nitrogen into the vent line, for the reason already stated that when the vent valve is opened, gas is released into the atmosphere, which leads to a potential risk of ignition when leaving the vent mast. Namely, in this situation, two of the three factors required for the fire, i.e. the closure of the burning triangle (heat source - flammable substance - oxygen) are met, and in that case even the smallest spark, which is the heat source, is sufficient for the fire. The presence of nitrogen in this mixture of gases, therefore, acts in a way that dilutes the flammable mixture of natural gas, and at the same time reduces the proportion of oxygen in the atmosphere immediately at the exit of the gas from the vent.

***PERC system***

The Powered Emergency Release Coupling (PERC) is a system responsible for acting in an emergency situation by quickly and efficiently stopping cargo transhipment processes and releasing all transhipment pipes with the help of specially designed safety hooks that are located at the junction of the terminal pipeline and the cargo LNG pipeline of the ship [11]. Also, the system can release the mooring ropes so that in the event of an emergency, the ship can be removed to a safe distance as soon as possible, either with its own propulsion or with the help of tugs. This applies to both the LNG transhipment vessel and the FSRU vessel. A PERC system arrangement is illustrated on figure 5.

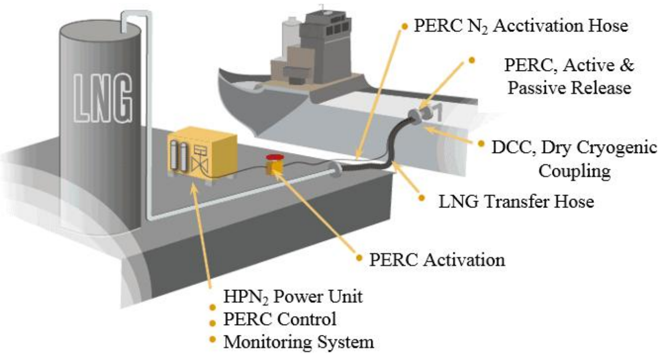


***Fig.5*** *PERC system arrang. Source: MannTek LNG Solutions, 21.10.2020.*

The system is connected to the aforementioned ESD system and is usually activated automatically as part of the safety factors of that system.

## 8. Security measures

When it comes to securing the FSRU terminal, emphasis is placed here on measures to prevent unauthorized persons from entering the ship and the surrounding area of the ship, to prevent possible acts of terrorism and to prevent other potential illegal actions related to terminal property such as vandalism, burglary, theft, damage, unauthorized drone shooting, unauthorized use of infrastructure, etc. [12].

The most important framework of measures in securing terminals is the application of the International Ship and Port Facility Security Code (ISPS), which sets a standard of preventive measures for protecting both the ships themselves and the ports or terminals. The basic goal of the code is proper protection, timely identification of threats and taking preventive measures to eliminate potential security threats, as well as the correct response in case of adverse events.

Also of great importance in the overall security of each FSRU terminal is the proper application of the International Safety Management Code (ISM). This code covers ships and companies at the same time, thus ensuring the necessary synchronization between ships and companies. Based on this code, a ship safety management system (SMS) is adopted, which prescribes safety management methods for each individual ship, and there is a specific person ashore who is in charge of the connection between the ship and the company on ISM issues and SMS, as well as to control the implementation of security measures.

## 4. Conclusion

Coastal areas around the world today are among the most important areas on Earth. Not only does an extremely large proportion of the world's human population live here, but the same is true for many plant and animal species. In addition, these areas represent an extremely valuable resource for all coastal states that have the ability to exploit it.

As in practice there are many cases in which the application of protective measures is required in the coastal area, this paper focuses on analysis of and practical application of safety and security measures of the floating terminal for the import of liquefied natural gas. This analysis illustrates how the proper implementation of safeguards can decrease the risks of negative consequences and disasters to the lowest possible level. No serious incidents have been reported since these terminals operate worldwide, as is the case in the entire LNG industry, due to the fact that the highest standards of safety and security in maritime affairs are present here, and the adopted protection measures are properly and timely implemented and, if necessary, improved. This is the main proof that a properly adopted system of coastal zone management and risk management, if adequately adapted to the specific problems that occur in the area, can result in the desired way, which is to reduce the risk of disasters in the coastal area.

The design, construction, operational procedures, and control of other coastal exploitation systems can be similarly organized. If problems are anticipated, noticed and identified in time, and approaches to solving them, by applying adequately adopted measures, the coastal area can certainly be positively affected in the long run. In this way, it is possible to reduce the risks of negative consequences and disasters, and preserve the coastal area, so that future generations can also engage in activities in this area. Respect for the principles of sustainable development, coastal zone management and risk management is the only correct path to be followed in any activity in extremely rich, but equally sensitive, coastal areas.

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