Abstract: This article examines the implementation of port terminals intended for the import of liquified natural gas in Brazilian territory and its importance to assure the continuity of energy offer, which historically has been one of the main factors limiting the economic growth of our country. The Logistic Chain of GNL is also demonstrated, as well as, the pre-requisites of safety, reliability and performance for the automation of a Port Facility for Flexible Reception of GNL, as well as the newly opened one in the Port of Pecém, Ceará.

Keywords: GNL, Automation, Terminal, Regaseification, Power resources.

1 Introduction

1.1 Economic Scenario

The growth of the Brazilian Gross Domestic Product in the first semester of this year will be between 5.5 and 6%, according to estimates of FGV, Getúlio Vargas Foundation and IBRE, Brazilian Economics Institute. The employment generation in the seven first months of 2008 was over 1.5 million new jobs, surpassing the prior record reached over four years ago. FGV and Consulting firm Ernst & Young estimate that the Brazilian economy is going to reach from this year to 2030 a cumulated growth of 150%.

Is there in Brazil the infrastructure required to allow for the expansion and development of the several segments of industry and trade, so that in the next few years, growth as estimated by such study may actually exist?

The study by FGV mentions as main limiting factor against the growth of the economy is the nonexistence of offer of energy for the expansion of the industry and trade sectors, which are, among others, the main drivers of the economic growth.

Along the last 20 years, whenever there was some retraction in the economy, it was caused by a crisis in the offer of power or by the implementation of an economic plan by the Federal Government. Collor Plan, implemented in 1991 can be highlighted, as, among other measures, it imposed to the domestic market the blocking of private capital and credit access, ending up by limiting the purchasing power of the population and the consequent compelled reduction in power consumption.

The electric sector has one of the highest levels of computerized processes, among the other sectors of the economy, rich in information collected in its major segments (generation, transmission and distribution), it is structured with branches intended to specific activities such as: operation, regulation and research.

Figure 1 demonstrates the close relation between power consumption and the growth of economy, since, through information, studies and projections from the main branches of the electric sector, we have one of the most accurate indicators for the projection of the performance of Brazilian economy.

1.2 Energy Scenario

Brazil has a strong vocation to generate power through the use of its hydric resources, and is the 3rd largest producer in this segment, according to studies of EPE, Energy Research Company.

There is still a large potential do be exploited, however, the profile of the projects for implementation of hidroelectric power plants has changed, since, nowadays, the environmental requirements for the construction of dams and creation of large reservoirs are complex.

The tendency that has been observed is the implementation of small hidroelectric center in the Amazonic Region, where there is the largest unexploited hidrologic potential, however, away from the may consuming centers, located in Southeast Region.
Although the changes suffered by the Brazilian Electric Sector Model in the last years have made the implementation of small centers attractive, the distance vs. location binomial still drives away the potential investors in the transmission of the power generated by these centers.

Historically, the power transmission sector has always been the "ugly duckling" of the electric sector, since the distribution and generation have always had higher attractivity for investments, given the facility to measure their end product and the value added to it, electric power.

The dependence on hydrology and the increase in consumption, due to the growth of the economy, have been contributing to the reduction of the cumulated water in the reservoirs of the main power plants every year, since, due to the climatic conditions of the plant, the dry periods have been more and more intense and wet periods have been less and less constant.

In this scenario, the implementation of thermoelectric power plants based on natural gas is extremely favorable. In dry periods, the use of thermoelectric power plants for the dispatch of power is more and more feasible, as this period is the most critical for hydroelectric power plants, that suffer with the reduction in the cumulated water in their reservoirs.

1.3 The Role of Natural Gas

The contribution of natural gas, the main source of fuel in thermoelectric power plants, for the Power Resources in 2005 was 5.7%, which corresponded to about 450 billion cubic meters, according to a study by EPE (Energy Research Company) performed for the projection of the Brazilian Power Resources in 2030. Figure 2 demonstrates the growth of onshore and offshore reserves since 1995.

In view of the turbulences and rumors of a possible shortage of natural gas as a result of the expropriation and nationalization of the assets of Petrobrás in Bolivia, the government identified the need of taking measures to avoid the rationing of power in the dry period.

In this environment, Plangás, Gas Production Anticipation Plan, was created, a strategic plan of Petrobrás to reduce such dependence on the international gas and assure the supply of the natural gas market in the South-Southeast, especially for thermoelectric power plants through aggressive goals and projects, represented by figure 3. Up to the end of 2008, the goal is to match the production to the current consumption, that is, 40 million m³/day of natural gas.

In parallel to Plangás, the discovered reserves of natural gas in the Basin of Santos, opened the way to major investors, with special interest in the power market, with the possibility of increase in the offer of gas in the domestic market.
2 Problem Situation

The Brazilian economy started to grow in an aggressive manner, accompanied by the need of building new plants for the generation of electricity. The main configuration applied to the new projects was the thermal one, based on natural gas.

One of the main factors for the selection of this kind of configuration is the flexibility in the installation, as a thermoelectric power plant, may be easily installed near the major consuming markets.

The easiness in its supply by a simple gas pipe is highly advantageous, if we compare the need of building power transmission lines with long distances for the transportation of the power generated for the consuming market, if we take, for instance, a PCH (small hydroelectric center).

![Graph showing Brazilian Reserves of Natural Gas](image)

**Fig. 2:** Brazilian Reserves of Natural Gas [2].

![Diagram showing main natural gas projects in Brazil](image)

**Main Projects for offer of natural gas in Brazil**

![Diagram showing natural gas production projects](image)

**Fig. 3:** Natural Gas Production Projects. Source: Petrobras, Plangás.
The short term for the implementation of a thermoelectric power plant and the low cost of construction are highly important attractives, since according to EPE, the construction of a thermoelectric power plant has one of the lowest costs in comparison to other types of power plants with 750 US$/kW.

The option for the implementation of the thermoelectric power plants was viewed by the governmental power research and planning entity as an alert for a possible crisis in the supply of natural gas, in view of the proximity of an expressive increase in demand.

More accurate studies evidenced the existence of a true logistical and technologic challenge for the exploitation of the natural gas found in the pre-salt in the Basin of Santos, where there is the reserve of Tupi and Júpiter, inspiring doubts as regards the actual possibility of producing gas in these fields in medium and long term.

From this moment on a need arises to seek a new alternative for the supply of the domestic natural gas market, in order to permit and assure the supply of gas to the new plants, which are vital for the security of the power supply. Thus, the risks of rationing could be driven away, preventing the occurrence of breaking in the rhythm of growth of industry and trade, the main drivers of the Brazilian economic growth.

In this scenario, it is necessary to look for alternatives to face an unavoidable crisis in the supply of natural gas.

3 Solution

The import of LNG (liquefied natural gas) as a possible solution to face an unavoidable crisis in the supply of natural gas was the solution adopted by the Brazilian government. A run against time was started for the implementation of the LNG Brazil Project.

LNG Brasil Project consists in the implementation by Petrobrás flexible port terminals for the reception of liquefied natural gas, interconnected to the mashes of terrestrial transportation of natural gas. The terminals located at Baia da Guanabara, Rio de Janeiro and Pecém, in Ceará will be operated by Transpetro, which already operates nowadays the gas pipes of the mashes of terrestrial transportation of gas.

The terminal in the Port of Pecém has capacity for regasification of 7 million cubic meters of gas/day, equivalent to about half of the current consumption of natural gas intended for the thermal market throughout the country. It also represents an increase of 11% in the current offer (Jul/08) of natural gas to the domestic market, which is of 60 million cubic meters/day. The gas processed in Pecém will be prioritarily used for the generation of electricity at the plants of Northeast Region.

The transportation of the LNG from the producing countries to the Brazilian terminals will be performed by ships adapted to perform both the storage of LNG and the regasification of the product aboard. Brazil is also a pioneer when adopting the model of transfer of LNG to a supplier ship to another regasifier ship through cryogenic arm, able to support temperatures of about -160º C.

Petrobrás contacted for ten year the tank ships with Golar Spirit and Golar Winter regasification units from Norwegian company Golar LNG. The first one has a storage capacity of 120 million cubic meters a day, dimensioned to operate with maximum flow of 7 MMm3/day (pressure of 100 kgf/cm2), whereas the second has a storage capacity of 139 million cubic meters, dimensioned to operate with maximum flow of 20 MM3/day (pressure of 100 kgf/cm2).

Golar Spirit is the first LNG carrier in the world converted to perform the regasification of LNG aboard. Besides the conversion of the natural gas from the liquid to gaseous state, it also stores LNG in its cryogenic tanks. The cost of the freight of the two ships will total about US$ 90 million per year, including operating expenses.

Taking as reference the undertaken in Port of Pecém, Petrobrás adapted the structure of pier 2, which operated as a terminal of petroleum byproducts, so as to prepare it to receive LNG. 2 concrete platforms were built to rise the height of the pier by 3 meters and a reinforce was made to the structure of docking and tying (dolphins) of the ships and facilities were mounted for the transfer of LNG from the external and the internal bed of the pier (piping system, valves and automation instruments), called central skid. These reinforcement works permit the anchorage of large ships, as the suppliers of LNG, and the perfect safety of the terminal.

The pier has about 340 meters long and the docking platform, with 45 meters long and 32 meters wide, will be shared by the LNG and liquid fuels infra-structure. In the terminal, six arms for transfer of LNG and two for Compressed Natural Gas (CNG) were also installed. Besides the interventions in the pier, a 22.5 km long gas pipe was built, which connects the terminal to the mash for terrestrial transportation of gas.

Brasil LNG project follows the most strict international safety standards. The standards and technical guidance of Ocimf (Oil Companies International Marine Forum) and Sigtto (Society International Gas Tanker and Terminals Operators) have been adopted. Petrobrás is a member of these
entities, which are international references in the sector. Among the additional safety measures adopted by the Company is an automation system that integrates the entire terminal. It is capable of making the full interruption of the transfer, both of LNG between ships, and of natural gas from the regasifier ship to the gas pipe upon any signal of abnormality.

All LNG and CNG connections have special valves for fast closing, if necessary. The transfer arms are also equipped with an emergency disconnection system, which provides two situations of operation. In one, there is the turning off of the loading pumps and the closing of the arm valves; in another, the disconnection of the arms from the ships.

Before operating, the place received the ISPS Code certificate, the international code that aims at the safety and protection of ships and port facilities, was prepared by the International Maritime Organization (IMO), belonging to the United Nations (UN) and approved by the Brazilian Government as a law. The operations will be supervised in a Control Room by 12 Operation technicians specifically trained to handle LNG. The terminal further counts on an emergency and fire fighting plan. The pier has vapor sensors which, in view of any suspected leakage, alert for the suspensions of the operations. Ultimately, the loading arms are decoupled from the supplier ship.

As if this all that were not enough, a tug boat will be 24 hours a day on duty, ready to operate if there is any occurrence outside the specifications. The ship will provide support to the regasifier and supplying ship. All this care will assure more power for the development of Brazil with full safety.

LNG will prioritize serve to supply the thermoelectric power plants that substitute the hydric generation whenever necessary. The fact is that the consumption of fuels was stimulated by the expansion in the economy (5.4% in 2007), the highest one in three years. Brazil consumed in average 71.2 MMm³ of natural gas per day in 2007 and the consumption may increase to 134 MMm³/day up to 2012, according to Petrobrás.

In 2012, the country will use 42.1 MMm³/day of natural gas to generate electricity, against 5.2 MMm³/day in 2007, Petrobrás gas and power director Graça Silve Foster estimates.

There are plans for the construction of a third terminal in the South region, because besides the contract with English BG Group, in Trinidad & Tobago, the Algerian company Sonatrach will also sell liquefied natural gas (LNG) to Brazil by reason of an agreement signed in May of the last year. Other potential supplier would be Nigeria LNG, however, a good portion of the gas that is required to meet the supply for the thermoelectric generation in Brazil is assured. Petrobrás has further negotiated a supply agreement with Omã and could even receive an additional supply of fuel from Qatar. However, some analysts believe that in long term, Brazil may face low offer of LNG, as it occurred with other potential importers of the fuel.

4 History of LNG

The technology of liquefaction of the gas was developed in the first half of the XX Century, with the purpose of extracting helium from the air. In the forties, this technology was adapted by the American natural gas industry, initially to store substantial amount of gas in a small space, considering the daily and seasonal variations in demand. In 1959, the first cargo of liquefied natural gas (LNG) was transported from the USA to England in a ship especially prepared for that product. The success of this travel led to the construction of the first LNG unit in Algeria, in the beginning of the sixties [3].

From Algeria, LNG initially reached England, then France and other European countries. In the end of the decade, one unit built in Alasca started the supply of Japan, which became along the time the largest importer of LNG, absorbing 60% of the world production, which reached 112.9 million tonnes in 2000. The American market, on the other hand, that was initially considered the largest potential consumer of LNG has not developed: today, only 2% of the world production flow to that country, but this situation is changing quickly. With the increase in the consumption accelerated by the use in electricity generation, the depletion of the American natural gas reserves, the LNG is in phase of resumption in the United States, with a prospective that, in the next fifteen years, it reaches 20% of the consumption of the country [3].

Today, we have eleven countries importing LNG and another twelve that are producers (Indonesia, Algeria, Malasia, Qatar, Australia, Brunei, Nigeria, Abu Dhabi, Trinidad and Tobago, Oman, Alaska (US) and Libia). In these countries, about 20 plants are operating, many of them under enlargement, supplying Europe and the Far East (Japan, Korea and Taiwan), and starting the supply in the American east coast. Figure 4 presents the facilities of production of LNG in operation [3].
The transportation between the production and the reception place is made in ships especially built for that purpose. About one hundred twenty of them are in operation and several others are being currently built throughout the world. There are recent estimates that the world fleet of LNG carriers will have to be doubled within the term from 5 to 7 years. In France and in South Korea, there are today ships in construction that may carry up to 153 thousand m$^3$ of GNL. Details of the type and other characteristics of these ships will be given below [3].

The production, transportation and regasification of LNG are operations that demand high investments, besides losses from 10 to 15% of the gas during the process, much more than an equivalent transportation through a gas pipe (losses from 1 to 2%). This causes the choice of LNG to be restricted in the cases in which gas pipes are not technically feasible (crossing deep seas), or where the transportation distances make gas pipes not cost-effective. In the current technology, after 4 thousand kilometers, the costs of a LNG system become compatible with those of transportation in gas pipes [3].

5 The LNG system

A LNG project is, actually, a sequence of activities from the production of the gas, liquefaction, maritime transportation, regasification in the destination up to the distribution.

The natural gas (GN) is transported through maritime ship in the liquid state. The transformation of the natural gas to the liquid state occurs under conditions of low temperature or under high pressure. In this state, the GN is called liquefied natural gas (LNG). Its volume reduces in by about 600 times. By economic and safety reasons, the NG is kept at a pressure slightly higher than the atmospheric pressure and its temperature reduced to -162º C through a highly power consumption process. This method permits, from the economic point of view, that the gas be stored and transported in LNG carriers (Figure 5), up to the terminals for reception or regasification. The transportation in the liquid state through ships is used only when the productions and consumption centers are at distances that economically justify its use. In the regasification terminals, the LNG is regasified and odoured so that it can be transported by gas pipes up to the consumption centers [4].

Figure 6 presents the chain of the natural gas from the production to the end consumer, including the step of liquefaction, transportation and regasification, in which we have the LNG.

6 Liquefaction Process

The liquefaction units initially make a treatment of the natural gas to remove the impurities (existing in the gases from the fields) that could suffer solidification during the temperature lowering process, such as water, carbon dioxide, sulfurous compounds, lubricant oils, mercury and heavy hydrocarbonates. These substances are removed up to a dose considered to be acceptable, according to international standards. The gas treatment process includes the separation of the liquefied petroleum gas (LPG), basically propane and butane, that may be sold as an end product or reinjected in the LNG [3]. Only after this treatment, the gas is submitted to the temperature lowering up to -162º C without significantly changing the pressure.
The set heat exchangers, the main part for the liquefaction, operates according to the same principle of a domestic refrigerator. The process most used are CRC (cascade refrigeration cycle) and CRM (mixed refrigeration cycle). In the CRC, the refrigeration is made in stages. Each stage involves one single refrigerant fluid that refrigerates the fluid of the following stage through compression and expansion processes, figure 7 [6]. The main difference between CRM and CRC regards the refrigeration fluids which are mixtures properly chosen of refrigerant fluids [4] [6]. The CRM presents higher efficiency than the CRC, however the ideal choice of the mixture of the refrigerant fluid, according to the parameters of the system, is a difficult of project [6].

The liquefaction units are built in places with good depth (at least 14 m), in a sheltered bay as closest as possible to the producing fields, are basically composed, as it can be seen in figure 8, of a treatment unit, the set of heat exchangers and the storage tanks.

The liquefied natural gas is stored in tanks that are capable of keeping it at -161°C up to the shipment. By reason of the high storage cost, its capacity is calculated by sophisticated processes that take in consideration the production of the unit, the number and size of the ships, risks of delay and other variables [3].

7 LNG Carriers

LNG Carriers are especially considered for the transportation of LNG with security requirements according to standards established by INCO (InterGovernmental Maritime Consultative Organization). The standards include requirements of construction, instrumentation, protection against fire, inspection, certification, operation in terminals, travel route and training of the crew and land person [4]. Standard ISO 17894 presents a set of required principles, recommended project criteria and a guide for the development and use of electronic systems that are programmable for use in ships. This standard is applicable to any equipment shipped that contain programmable elements that may affect the security or efficient operation of the ship. The principles involved in this standard are based on international standards and rules [7] [8].

There are basically two types of LNG carriers: the one that stores gas in spheres (called Moss Rosenberg) and those that have tanks in the conventional positions of oil ships (called membrane or Technigaz type) [3]. Currently, the ships with spherical tanks are the preferred choice of the carriers. The spheres are made of a steel alloy with 9% of nickel, with capacity to store over 25,000 cubic meters of LNG that represent 11,125 tonnes. The largest ships contain five spheres and are capable of transporting over 125,000 cubic meters or 55,625 tons. For a continuous consumption of natural gas, of 15,106Nm3/day, a ship of such size would have a reserve for five days. In the lower part of the spheres there are containment spaces that are sufficiently large to accommodate possible leakage. The tanks are protected against frontal collisions, as the ship has an elongated prow and the hull of the ship, build with double plates, offers lateral protection. The capacity of maneuvering at low speed is facilitated by the prow bulb. Within the storage tanks there are pressure, temperature sensors and liquid level markers. The thermal insulation is made with rock or glass wool, involved by a layer of fiberglass [4].
For many years, the Japanese dockyard prevailed in the construction of such ships, but nowadays they are also being produced in Finland, Italy, France and especially in South Korea [3].

8 LNG reception terminal

The main components of a LNG reception terminal are: equipment for unloading of LNG from the tanks of the LNG carrier, special LNG storage tanks, boil-off gas compressor, BOG compressor, cryogenic pumps, recondenser and vaporizers. The terminals are also responsible for the odorification of the gas [4]. Figure 9 presents a typical process diagram for LNG reception terminal [9].

The capacity of the storage tanks may go from little more than the load of a ship (the case of Huelva, in Spain, with 160,000 m³ of storage, for ships of containment walls to avoid the possible leakages spread the liquid through the surroundings, causing fire that would be catastrophic [3]. Internally to the tank, the pressure is little higher than the atmosphere, about 0.5 psi (3.4kPa), keeping the gas lightly compressed to avoid natural vaporization [4].

Due to the low temperatures involved in the tanking system, special attention is given to the instrumentation and automation system. This includes the alarm system, emergency shutdown system – ESD and fire and gas detection system - F&G). The tanks are also equipped with pressure relief safety valves – PSV and vacuum breaking valves that assure the integrity of the tank in adverse situations. As the tank simultaneously sends and receives the LNG cargo of the ship (figure 9), pressure control valves - PCV are used to prevent the excessive accumulation of boil-off gas – BOG internally to the tank. Temperature and density measurement devices are installed along the height of the tank to detect the stratification of LNG (formation of layers with different densities) besides level meters (typically capacitive and/or radar) for the control of the level of the tank and overflow detection [9]. Section 10 will present the capacitive and radar type sensors, for measurement of level, that are applicable at low temperatures in further detail.

BOG is normally produced in the terminals due to an even small heating transfer in the lines, in the tank and in the ship. The BOG compressor, together with the recondenser, liquefies BOG, transforming it again in LNG (figure 9) [9].

![Process diagram for a typical LNG reception terminal](image-url)
The pumps of the first stage work submerged in the LNG. They are typically high-capacity low-pressure electric motor pumps. The LNG pumped also passes through the recondenser. The pumps of the second stage work under high pressure to send LNG to the vaporizers at the pressure of 75 to 80 Bar [9].

The vaporizers are responsible for regasifying the LNG and send it for consumption. Before passing through the regasification, the LNG is pumped until it reaches the pressure and the inlet of the gas pipe. If the compression were made in the gas state, the consumption would be much higher.

The vaporizer is a heat exchanger made out of pipes, within which the LNG passes. Typically, sea water is used in an open circuit or a hot water bath (heated with the burning of gas) to exchange heat for the LNG, making it reaching the room temperature and, thus, regasifying it [9].

This kind of evaporator is reliable, safe and economic, since it depends only on the flow of sea water. An average size evaporator that uses sea water is capable of producing 95 tonnes per hour of natural gas and consumes, in average, 4100 cubic meters of water per hour [4].

The process of vaporization of one kilogram of LNG consumes 502.4kJ in the form of latent heat and 335kJ in the form of sensible heat. With this data, it is possible to calculate the power resulting from the use of the “cold energy” of the LNG regasification process, for the production of electricity. A liquefaction terminal that produces a flow of 15 million cubic meters a day may feed a thermoelectric center with 107.8MW capacity, at virtually zero energy cost [4].

The energy consumed in the liquefaction centers is also recovered in the reception terminals as “cold energy”, in industrial processes such as frigorific chambers, manufacture of oxygen, of carbon dioxide and dry ice, as well as the production of frozen food. In order for this recovery to occur, the reception terminals are large industrial complexes involving very high investments [4] [3].

The thermoelectric generation is made through a Rankine cycle, in which the sea water operates as a hot source and LNG as a cold source. The fluid that performs the cycle, called MFR, is pressurized in the liquid state so that it later passes through the vapor generator, in which it receives the heat from the sea water. MFR passes through the turbine as vapor and goes to the condenser, whose cold source is LNG. It receives the heat from the MFR and passes to the gaseous state. After passing through another heater with sea water, the natural gas is led to the gas pipe, and from there to the consumption center [4].

The cargo of a LNG carrier that carries 125000 cubic meters, if fully used in the thermoelectric generation in the regasification process, may produce 176MW in a continuous process, for 5 days [4].

9 Safety in LNG reception terminals

In 1942, in Cleveland, USA, two storage tanks were built in a high place and without containment walls. The material from the tanks was steel alloy with 3% nickel, when it should be 9%. This permitted in 1944 the breaking of the tanks and the spilling of LNG that spread through the surroundings, causing fire that killed 128 people. Several other accidents with fatalities occurred in the world in LNG handling terminals. Due to the involved risk, the automation technologies have been evolving with a strong tendency of minimizing the action of the operator and promoting an efficient control to reduce the risk situations of the LNG processing plant [4] [10].

The distributed control system – DCS and fire and gas detection system – F&G provide the information to the terminal operation room. The detection devices, visual and sound alarms are strategically positioned along the terminal. The detection devices typically used are: detection of flame, heat, smoke, low temperature and gases.

The closed circuit TV (CFTV) provides images from the critical equipment from the operation room. The emergency shutdown system, ESD permits that the plant or any part of it, to be safely and manually shutdown by the operator or automatically when a set of operation safety restrictions of the plant is violated.

The main subsystems to be controlled by DCIs are: cargo control of the plant, storage tanks system, control of vaporizers and power generation.

An automated plant uses a DCS that performs all possible functions for the less actuation of the operator. The controls involve real time calculations, for instance, the balance between demand and cargo, permitting that the vaporizing equipment are turned on or off automatically. The ESD always operates independently, and does not need the demand of the operator, as it has the main purpose to avoid accidents within and outside the factories, such as fires, explosions, damages to the equipment, protection of production, property, and avoid damages to personal heath and catastrophic impacts for the community and the environment.

The functional safety of ESDs comprises the safety of the plant, which depends on a system or equipment correctly operating in response to its input. Thus, the IEC (International Electrotechnical Commission) presented in standard IEC 61508 (Functional safety of...
electrical/electronic/programmable electronic safety-related systems) the basic requirements for functional safety of the electronic systems used in industry [11]. The requirements exposed in IEC 61508 are also applied in the LNG regasification plants [10].

The current market presents several ESDs implemented in different ways. Some manufacturers apply redundant logics to provide a higher level of safety, as it is the case of the triple redundant programmable logical controllers manufactured by ICS Triplex or by Triconex-Invensys. Otherwise, the programmable system ProSafe-RS of Yokogawa manufacturer implements the level of the safety integrity without the use of redundant logics [10].

This concept of safety level is represented by the Safety Integrity Level, SIL introduced by standard ISA 84.01 and IEC 61805-1 [12]. There are similar concepts presented in other standards, such as DIN V 19250 from the German Standardization Institute (Deutsches Institut für Normung, DIN).

The concept of SIL establishes an order of measurement for the reduction of risk or, otherwise, the required level of soundness to be implemented so as to reduce the risk of the process to acceptable levels. The SIL is classified and represented by numbers that vary from 0 to 4. The more critical the process is, higher is the required SIL [12]. Table 1 presents the relationship between the SIL level and the probability of failure in demand (PFD) of the equipment.

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<th>SIL</th>
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<td>0</td>
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The SIL of the safety control or interlocking mash may have a probability of failure in demand compatible to SIL 3 [12].

The risk of the process may be determined through a process hazard analysis (PHA). In short, the way of measuring the risk is based on the product of the Frequency at which a certain event occur (F) by the Consequences resulting from the occurrence of an event (C). So, Risk = F x C [12].

The electric facilities in atmospheres that are potentially explosive are risk facilities. The equipment and common electric components may cause its ignition through a spark or a hot surface. Therefore, the equipment that is exposed to potentially explosive atmospheres or that interface with equipment exposed to potentially explosive atmospheres, as it is the case of the environment of a regasification plant, must be prepared for that, according to the ordinance 176 of the National Metrology Standardization and Industrial Quality Institute (INMETRO) [31].

Article 1 of this ordinance says: “Keep the obligation that all electric equipment, accessories and components for potentially explosive atmospheres traded and used in Brazil in compliance with the legislation in force, other than the exceptions set forth, show the identification of the certification from the Brazilian certification system”.

The equipment compliance certificate is the guarantee to the consumer, as it certifies that the product is in compliance with the technical standards.

In Brazil, standard NBR IEC 60079 (Equipamentos elétricos para atmosferas explosivas) issued by ABNT (Brazilian Technical Standards Association) establishes the rules for labeling (identification), construction requirements, directives for tests, inspection and maintenance and other standards for electric equipment applicable to potentially explosive atmospheres. [14].

There are several forms of implementing the proper protection for the application of the electric equipment in a potentially explosive area: hermetically sealing the equipment (call Ex-s protection), limiting the power stored and demanded by the equipment (called Ex-i protection), etc. The protection must not interfere with the proper operation of the equipment. The type of protection to be chosen mainly depends on the flammable product likely to be in the atmosphere and its probability of occurrence.

10 Instrumentation and automation technologies for LNG reception terminals
The automation system for a LNG regaseification terminal must be designed and considered as an instrument for the production areas to reach their goals of:

- Production;
- Cost;
- Quality;
- Safety;
- Environmental Control.

The offer of solutions in DCS and/or SCADA software or even both present in a hybrid architecture in the control and emergency shutdown (ESD), must have solutions that increase the efficiency of the processes, increase productivity, distribute information and increase the competitive capacity of the organizations. For that purpose, they must be designed so as to:

- Present high availability and be easily accessible to the operators;
- Permit the evolution compatible with the evolution of the knowledge of the processes and the operating practices;
- To be developed in an integrated manner (instrumentation, electric control, supervision/optimization of processes, production planning and control);
- Incorporate facilities of making available remote information through Internet technology.

The full domain of the systems by the technicians of the organization itself is fundamentally important. Therefore, they must be preferably acquired:

- In a totally open manner in terms of hardware and software;
- With the proper documentation and training;
- The rationalization of maintenance resources must be sought;
- The diversification of equipment and software must be minimized.

If there is a need for a wide range of rotary equipment (BOG compressors, cryogenic pumps, etc.) and electric/electronic devices, with systems for generation, transmission and distribution of power, water handling, automation, telecommunications, industrial IT and safety support systems, countless solutions must be designed to assure an excellent performance of the plant.

The market offers solutions for power supply, automation, driving and IT for LNG receiving terminals. There are integrated solutions in automation and control for unloading (jetty, tying up, anchorage), storage plant, storage tanks, boil-off gas compression, vaporizer and distribution systems. These solutions available may assure a level of safety integrity of up to SIL 3. Below please find the automation solutions available in the market [15].

1. Terminal Management:
   1.1. Distribution planning;
   1.2. Batch management;
   1.3. Reconciliation of product and inventory management;
   1.4. Integration of commercial systems;
   1.5. Personal access control system.

2. Automation and safety systems:
   2.1. Emergency Shuttdown (ESD) Systems;
   2.2. Fire and Gas (F&G) Protection systems;

3. Terminal Automation:
   3.1. Automated loading process;
   3.2. Tank checking;
   3.3. Regaseification process automation (DCS);
   3.4. Control of jetty (DCS);
   3.5. Control of anchorage and tying up;
   3.6. Control of large machines such as BOG compressor;
   3.7. Ship-land communication.
   3.8. Supervision system (Supervisory Control and Data Acquisition, SCADA)

4. Instrumentation
   4.1. Process Instruments/Drivers;
   4.2. Capacitance-based level measurement systems;
   4.3. Radar-based level measurement systems.

Most systems listed are not specific applications for LNG or LNG carriers. Specifically, the instrumentation for level measurement has its own characteristics to be applied at very low temperatures, as it is the case of LNG storage. Manufacturer Siemens presents the SITRANS LC500 capacitance-based, cryogenic level meter for application in LNG terminals. Figure 10 shows a typical capacitance-based level meter installed in a tank.
SITRANS LC500 is comprised by a transmitter with output in standard 4-20mA and HART [16] communication for remote calibration and inspection. The probe is, in general, a sensor and is of capacitive nature, where the variation of capacitance is associated to the variation of the level of liquid in which the sensor is immersed. With the variation of capacitance a displacement of phase occurs in the alternate signal that drives the sensor. Thus, it is possible to obtain high resolution in the measurement. The sensor is electrically insulated, and there is no contact with the liquid. This may work at low temperatures up to -200ºC.

The technique for level measurement and interface in LNG tanks using radar is growing. The main reason is, as well as the capacitive technique, the nonexistence of mobile parts and that need maintenance [3].

The advantage of the radar in relation to the capacitive meter is, especially, the nonexistence of physical contact of the product (LNG) with the meter. The radar emits electromagnetic waves and receives the echo (reflected wave) from the surface of LNG and/or the stratified interfaces of the LNG, as mentioned in section 8. Basically, from the delay between the signal issued and the one received (echo) the meter identifies the level of LNG and the levels of the stratified interfaces. Manufacturer Rosemount presents the TankRadar Rex RTG 3960 (figure 11) as the solution for measurement of LNG tank levels, bearing temperatures down to -170ºC. This meter uses the frequency modulated technique (frequency modulated continuous-wave radar, FM-CW) to measure the level. In this technique, a triangular signal modulates the frequency of the electromagnetic waves emitted. Through the correlation between the modulating triangular signal and the detected triangular signal, the propagation delay is identified. By knowing the speed of propagation of the electromagnetic wave in the medium (vaporised in the tank) through calibration, the tank level is identified [17].

To control against surge and the capacity of the BOG, the manufacturers of compressor control systems are presenting a solution based on the automatic adjustment of the gas inlet guide vanes, IGV, to avoid the stall. The angle of the vanes is adjusted according to the temperature of the incoming gas and the speed of rotation of the compressor shaft. This geometry adjustment of the BOG compressor permits higher flexibility to the control and operates in parallel to the conventional recirculation (bypass) system [18]. Siemens supplied in 2003 one of such system for BOG compressor of the terminal of Altamira in Mexico [19].

11 Conclusions

The operations of import of the liquefied natural gas mark a new age in the supply of gas in the Country, which will have higher flexibility and safety in its offer. The tendency of using imported LNG for the supply of thermoelectric power plants avoids the risk of a stoppage in the rhythm of growth of the economy caused by a possible crisis in the supply of power.
Given the adverse scenario of operation of the process equipment of an LNG reception terminal (low temperatures, in particular), the manufacturers of instruments and equipment for automation and control of process plants make available specific products for application in LNG reception terminals. The project criteria present in the standards in force together with such instrumentation and automation permit to implement terminals considering the safety and operational continuity, which are essential facts in an LNG system in view of its importance for the set of power resources.

The LGN Brazil Project has important developments through the socioeconomic impacts resulting from the construction of the LNG Flexible Terminals. In the region of the Port of Pecém in Ceará, the local economy is in full expansion, as they are attracted by the assured supply of gas.

References:


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