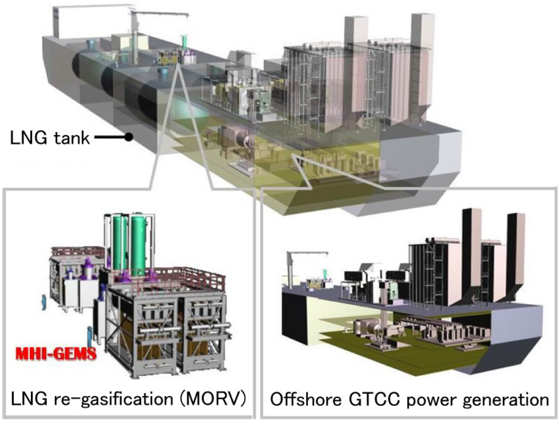
Offshore Deployment of LNG supply chain –Floating LNG Infrastructure–



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Natural gas is just as an important primary energy source as petroleum and coal. Due to its abundant reserves and cleanness of combustion gas discharged into the environment, no one could argue with the presumption that its position will last into the future. In Japan, natural gas is imported as LNG and the vaporized gas accounts for the largest part of the electricity and heat supply. The gas supply chain for LNG has supported Japan's industrial infrastructure for over 40 years. The LNG supply chain will also be expanded into new markets including emerging countries with rapidly increasing electric power demand because of the growing supply and falling price as new natural gas resources will be tapped more. This report assesses the future LNG supply chain based on our experiences in the LNG/gas businesses in which we have been involved.

1. Introduction

LNG and natural gas are environmentally friendly fuels, because sulfur contained in LNG or natural gas is removed in the production process, and in their use as fuel in internal combustion, the generation of nitrogen oxides and soot and dust in the combustion gas can be reduced to an extremely low level. Natural gas is produced on a large scale in many places around the world and traded through pipelines or in the form of LNG among many countries. Since Japan is located far away from the major production fields, transportation in the form of LNG has almost been the only choice for us. Under such circumstances, Japan has long been the world's largest LNG importing country and has developed facilities and technologies for the infrastructure for the supply chain of LNG production, transportation, storage, regasification and gas-fired power generation, and so forth.

Lately, in many countries throughout the world, such as advanced industrialized countries making earnest efforts to preserve the atmospheric environment, countries wanting an energy transportation system barely affected by geopolitical risks and emerging countries with a rapidly growing electric power demand, the need for LNG is rapidly increasing. In the shipping field, too, the demand for LNG is increasing, and mainly because environmental measures for controlling atmospheric pollution of coastal countries are increasing, use of LNG as ship fuel is being promoted. The rise in the demand for LNG for the medium and long term is supported by the increase of production capacity on the supply side typified by the development of shale gas and submarine gas fields off the African coast. Japanese industries that have led the way in the use of LNG have the potential to produce and foster new businesses under the circumstances where supply and demand are increasing.

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2. New deployment of supply chain

2.1 Conventional supply chain

Conventionally, natural gas resources unevenly distributed in areas away from major consuming regions were transported through ground or submarine long-distance pipelines or in the form of LNG. The LNG transportation method requires a larger investment in the supply chain compared to transportation by gas pipeline, and so it is adopted in consuming regions where long-distance transportation by sea is more advantageous or laying of gas pipelines comes at a higher cost. As of 2015, LNG accounted for about one third of total gas consumption.[1]

Figure 1 shows the supply chains of natural gas, including LNG. The left shows the present status and the right colored part indicates the expected deployment in the future. In the case of natural gas, mined source gas is refined and then distributed, while in the case of LNG, natural gas is liquefied by refrigerating equipment and transported to consuming regions by special cargo ship. (In transportation to inland regions, vehicles are used, but on a small scale.)

For primary transportation of LNG, an LNG special cargo ship[2] with an insulating container of 100 thousand to 200 thousand m^3 is used. LNG is off-loaded in a liquid state with a nearly atmospheric pressure (about -160°C), stored, re-gasified and consumed as power generation fuel or city gas as appropriate. Large-scale urban power generating facilities (e.g., power station complexes with gas turbines and steam turning-GTCC) efficiently consume a large amount of gas. So, such facilities are generally set up adjacent to an LNG receiving base, and gas is fed to small-volume gas consumers by the city gas pipeline network. In some cases, LNG is transported as is in small volume to a satellite facility. For a transportation volume of over several hundred cubic meters, a small LNG ship is used, and for several tens of cubic meters, a tanker truck is used.

Recently, however, for transportation of an intermediate volume (several thousand to several tens of thousand cubic meters), use of LNG as ship fuel has received a lot of attention.

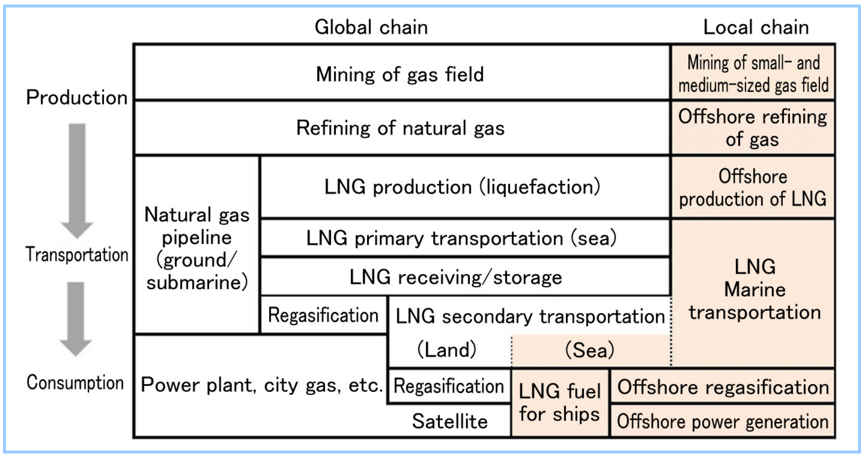

Figure 1 Supply chain of natural gas focusing on LNG

2.2 LNG as alternative ship fuel

Currently, ship fuel is heavy oil, which is produced as residue generated from the crude oil refining process. Along with the increasing awareness of environmental preservation, regulations for exhaust gas emissions from ship engines have been enacted, and now a drastic review on the use of heavy oil as fuel is required. Various measures such as reduction of sulfur content in heavy oil and installation of an exhaust gas scrubbing device in engines have been tried. Use of LNG is one of the alternative measures. LNG as a fuel for ships has been studied for various types of vessels, and actually, some small ships for which LNG can be fed by truck have begun to appear.

Also, there are a number of projects for larger ships planned to be equipped or that it is assumed they will be equipped in the future with LNG fuel facilities, but they are awaiting emerging LNG bunkering points, that is, LNG bunker ships and their related infrastructure. A bunker ship, which is similar overall to a small LNG ship, needs to have the facility and function to deliver LNG to various types of ships. At present, bunker relay terminals and LNG bunker ships are being constructed mainly at the same sites as ship fuel supply bases. The world's largest bunker base in Singapore is planned to start supply of LNG at the beginning of 2017.

On the other hand, there is a possibility that the establishment of secondary transportation technologies for LNG will be useful not only in the use of LNG bunker ships but also for transportation within regions limited to emerging countries (regions).

2.3 Measures for demand in emerging countries

LNG calls for capital expenditure larger than that of other fuels. Now we specifically propose a "local supply chain" for which investment is limited so as to make use of LNG sustainable even in small cities (regions). This proposition is promising in emerging countries showing remarkable industrial development, particularly in Southeast Asia, South Asia and Central and South America, and we also expect it to help industrial development in Africa.

These regions seek the rapid and low-cost securement of electric power. Because these regions are in the process of development, however, at the onset, the power demand starts at a low level, but establishment of the local supply chain in a short period is required.

The proposal to form a local supply chain with the introduction of floating-type production and receiving facilities allows stepwise expansion in investment starting with small-scale investment and completion in a short period.

2.4 Offshore deployment of LNG supply chain

An LNG delivery station and an LNG receiving station positioned at both ends of the supply chain are located in coastal areas for connection with shuttle ships, and so the conditions for converting them into offshore facilities have been met. There have already been many actual examples of Floating Storage and Regasification Unit (FSRU) and Floating Storage Unit (FSU) which are offshore receiving stations. Also for production of LNG at the upstream end, there are many projects for LNG Floating Production, Storage and Off-loading facilities (LNG FPSO, generally referred to as FLNG). Some FLNGs are expected to begin operation sometime around 2017. For example, Shell, an oil and gas major in Europe, is undertaking the development of a submarine gas field in Western Australia, although no FLNGs have started operation as of April 2016.[3]

It is expected that the construction trend of floating an LNG production unit will be further promoted by subsea mining of gas resources. The existing offshore facilities are intended mainly for a global supply chain whose annual output greatly exceeds one million tons. Some facilities are designed for small- and medium-sized LNG floating production units[3], but generally, such a scale is regarded as being economically difficult to realize. This restriction in terms of the scale due to economic difficulties must be overcome. The small- and medium-sized gas fields dotted about Southeast Asia and the Caribbean Sea have middle-sized emerging city-type consumption areas in their vicinity. By forming an independent chain connecting such gas fields and consumption areas by a set of floating units and shuttle ships, the possibility of redevelopment will be increased. In addition, these emerging consumption areas require a supply of electric power first and foremost in many cases, and it’s even convenient and efficient if the vessel supplies electric power to the shore instead of supplying gas to the power system onshore.

3. Proposal of LNG floating facility

Our company has been heavily involved in the LNG supply chain business through the building of LNG transportation ships and the construction of LNG receiving stations and gas-fueled power generation facilities. The examples of specific proposals for offshore deployment of facilities constituting a supply chain and expansion of local supply chains based on those accomplishments are introduced.

3.1 Advantages of floating facility

Figure 2 overlooks the whole picture of the proposed supply chain. For stepwise expansion with limited initial investment, large secondhand ships conventionally used for transportation of LNG or LPG are converted and used as FSUs for storage of LNG. Used ships such as bulk carriers (dry bulkers) are also converted for LNG production and regasification facilities. For an LNG storage tank, a pressure container type (Type C specified by IMO) is used without any additional requirements such as building of secondary revetments, which are used for additional storage capacity, while FSU is used for the main storage capacity. Individual floating bodies are connected by hard arms installed to fixed piers (jetties), which are proven as LNG or gas transfer facilities or STS (Ship to Ship transfer) using flexible hoses. Modification of used ships can halve the time required to newly build facilities.

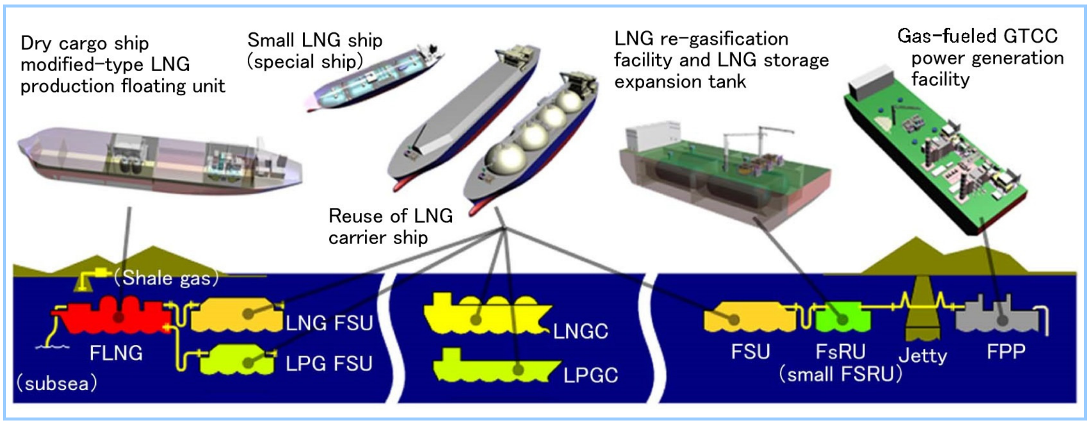

Figure 2 The overall image of the supply chain

In addition, even in a region where the infrastructure around the site has not been fully established and the offshore supply area becomes larger, a floating-type unit can be built together with lifelines at a dockyard and then they can be carried in the site. As such, the floating type is advantageous in deployment in emerging countries, which typically require stepwise enhancement of facilities through relocation or displacement, or in development of gas fields. The following details the supply chain of our proposition.

(1) Floating-type LNG receiving facility

The central right view in Figure 2 is an LNG floating receiving facility consisting of FSRU or FSU. LNG received from shuttle ships is stored in an FSU made utilizing a used LNG ship, is transferred from the FSU to the adjacent FSRU and is turned into high-pressure gas for delivery. FSRU is a barge-type floating body equipped with an LNG pressure container and a regasification facility. In this example, as a regasification facility, the MORV (Marine ORV) is used, which has been redesigned based on the ORV (Open Rack Vaporizer, which has been adopted as the main vaporizer for onshore receiving facilities), so that it can be used in a floating facility. MORV has a compact design and provides sufficient space for future re-gasification capacity expansion. The storage capacity of FSRU is selected so that the total storage capacity of FSRU and FSU becomes larger than the transportation capacity of a shuttle ship. Since the capacity of LNG ships has been increased stepwise, the younger the age of the ship, the larger the size of the ship. Thus, consideration must be given for the receiving capacity of FSRU.

(2) LNG floating power generation facility (FSRU, FPPU)

The foremost demand of emerging countries is electric power. So, it is more efficient to convert LNG into electricity for supply than to deliver natural gas. The right-most view in Figure 2 is one example of an LNG floating power generation facility (FPPU) proposed by our company. High-pressure gas received at FPPU from FSRU is consumed during power generation. In the onboard power generation facility, the natural gas-fired Gas Turbine Combined Cycle (GTCC), which has a high thermal efficiency, and also with consideration given to environmental preservation, is used. It is estimated that the market demand for the output range is from 100 to 300 MW/unit. For this range, among the gas turbines of proven LNG thermal power generating performance, the H-series gas turbine made by Mitsubishi Hitachi Power Systems is the most suitable.[4]

(3) LNG floating production facility (LNG FPSO = FLNG)

It is projected that an LNG production floating body produces one million tons or less per line annually. For the liquefaction process of this scale, a steam turbine driven-type nitrogen expansion cycle, which has a proven performance in actual use at the marine LNG re-liquefying plant, is the most suitable. The liquefying plant with the combined use of the nitrogen expansion cycle in a cascade manner, an off-gas combustion-type boiler and a reheating-type steam turbine driver which is derived from marine propulsion use, exhibits a high operation rate, low maintenance cost and less investment. At the same time, it realizes a high liquefaction efficiency comparable to larger plants for onshore use. Together with the pressure vessels for provisional storage tanks, it is modularized by each train, considering installation at the time of modification of a used ship such as a bulk carrier.

(4) Small shuttle ship, LNG bunkering ship

For a secondary transportation ship such as a shuttle ship only for the local chain and a supply ship for an LNG fuel ship (LNG bunkering ship), it is not sufficient that it has only a reduced transportation capacity compared to that of a large LNG ship employed in primary transportation.

It is regarded as more economical, depending on the cargo capacity, to use, as a cargo tank of the secondary carrier, a pressure vessel (IMO Type C) than a large container vessel (IMO Type B, etc.).[5] Our company proposes use of a Type C pressure tank for a small ship having a cargo capacity of 30 to 40 thousand m^3 or less. The inside pressure can be set so that boil-off loss of cargo LNG will not occur, and an additional refrigerating unit can be installed for reducing LNG temperature. On this ship, cargo LNG can be used as propulsion fuel in addition to fuel oil. Such LNG fuel supply package is already on the market, as you see on an example of our marine machinery product MHI-GEMS.[6]

3.2 Advantages of one-stop supply

To realize a facility like FLNG in which all the functions are complicated, a number of companies such as shipyards that build ship bodies, EPC companies that coordinate LNG-related facilities (top side) and process licensers must cooperate in operations. Those organizations (companies) that have different specialties are involved in their own parts of the work. Ambiguity of the scope of responsibility at the boundary of each work area is unavoidable and any risk arising from such ambiguity must be borne by the customer side.

Our company owns shipyards and affiliated companies such as EPC and related equipment manufacturing companies, and we can receive orders for the floating facilities described above and offer one-stop operations as a business unit. Customer's risks and burdens as described above can be minimized through expansion of our supply area.

4. Conclusion

In the LNG floating facilities of the supply chain introduced in this report, the important points are not only building the ship’s body and supply of shipboard instruments/equipment but total engineering for understanding the closely related facilities as a whole chain and provision of one-stop services.

Our company provides one-stop solutions for LNG infrastructure based on our experiences and technologies fostered through the marine business including LNG shipbuilding and sale of marine gas facilities (MHI-GEMS), the gas fuel power generation business and the LNG plant business including EPC of receiving facilities.

We hope that the technologies and businesses introduced in this report will be of some help to customers who develop new businesses in the fields of LNG production, receiving, storage, power generation, and so forth.

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