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Challenges and Strategies for Commissioning of FLNG

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Abstract

After the construction of offshore plants, the function and integrity of system in offshore plants should be commissioned. As the executor of many FLNG projects, Samsung Heavy Industries Co., Ltd has faced some challenges for commissioning which are not similar to those in other offshore project. This study shows the differences between the commissioning of typical offshore projects and the one of FLNG projects. By the characteristics of offshore, performing the commissioning activity of FLNG near shipyard as much as possible reduces the risk of malfunction. The possible solutions to achieve these strategies are introduced.

Keywords: FLNG, Commissioning, Mechanical completion, Pre-commissioning, Liquefaction plant, LNG containment system

1. Introduction

Generally, the commissioning activities for typical offshore plant have been carried out at the offshore site location by the major oil company that ordered the offshore plants. But, the challenges for commissioning activities of FLNG projects are arisen due to the difference of scope and design with other offshore projects. The condition of shipyard is not enough to check all equipment or system on FLNG before the sail away to the site location. The possibility that the failures of equipment or system on FLNG occur is low but if the failures occur, the huge amount of resources including manpower, time and facilities have to be injected at the site location. Normally, the approach to solve the problem like this costs more than the modification work at the shipyard. This paper shows the possible solution how to eliminate this kind of risks. In practice, the some solutions introduced in this paper are not applied to the actual FLNG projects.

2. Commissioning of FLNG

2.1 Scheme

The systems which are installed on FLNG are various for each one. Representative systems of FLNG using the mixed refrigerant for liquefaction module are presented in Fig. 1. The green colour box stands for the systems to be completed at the shipyard. However, the blue colour box stands for the systems to be completed at the site location due to the constraint condition. Those systems include LNG/LPG storage systems, sea water lift system and turret mooring system. The timeline is presented in Fig. 2 based on the sail away when FLNG leaves the shipyard for towing to the site location. The sail away separates the location where the commissioning activities are carried out. The commissioning stages at the shipyard are not assorted exactly.

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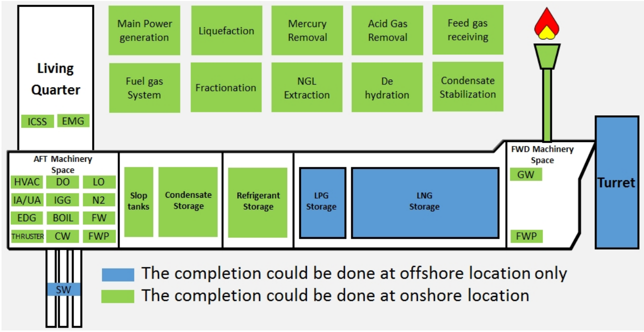

Fig. 1 Systems of FLNG

Next commissioning works for each system are carried out as soon as previous commissioning works are done simultaneously. And, the commissioning works are finished before the sail away. Next to commissioning works at the site location, the whole facilities start up and the feed gas is injected to the facilities for the performance test. The facilities of FLNG are operated and modified to perform the guaranteed performance during the performance test.

2.2 Challenges

The risks which can affect the project are found while preparing the commissioning works of FLNG projects. Especially, if the problem occurs during the commissioning at the site location, those impacts influence the schedule of project.

Failure of LNG containment system

The technology to store LNG at the offshore mostly is GTT's MARK-Ⅲ technology. In case of MARK-Ⅲ technology, Secondary Barrier Tightness Test(SBTT) is carried out to check the integrity of the LNG containment system. SBTT is executed after the gas trial of which the LNG is stored in LNG containment system. Generally, the gas trial for LNG carrier which MARK-Ⅲ technology is applied to is executed in the sea near shipyard. The LNG carrier receives LNG from the LNG terminal and moves to the sea near the shipyard for the remained process of gas trial. The reasons that LNG carrier can receive LNG from the LNG terminal are those the appropriate propulsion system is installed on the LNG carrier and the jetty of LNG terminal is fitted with the LNG carrier. In contrast, the general FLNG does not have the propulsion system and the dimension of FLNG is not suitable for the jetty of LNG terminal. So, in case of FLNG, receiving LNG is done by the side by side loading from the LNG carrier at the site location after the installation of mooring lines. Consequentially, the gas trial of FLNG is executed at the site location with the procedure presented in Fig. 3.

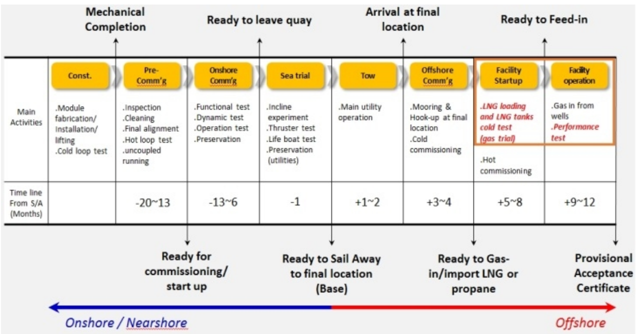

Fig. 2 Timeline of FLNG's commissioning

Table. 1 – Typical guaranteed performance of FLNG

Performance Guarantees	Description
LNG/LPG/Condensate	Quantity, specification and quality shall satisfy guaranteed figure.
Power consumption	Power consumption at the guaranteed production rate ≤ design criteria
Individual Process/Utility Unit	Individual Process/Utility Unit shall be capable to perform in accordance with design criteria

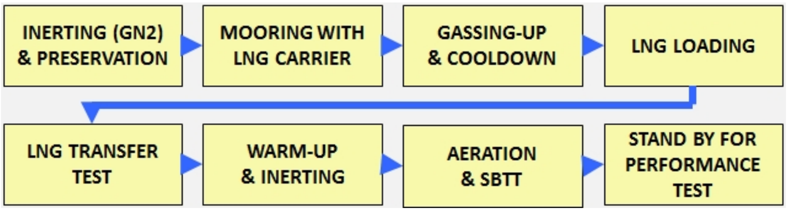

Fig. 3 – Gas trial procedure of FLNG

If the flaws of LNG containment system are found after SBTT, the repair works are required at the site location. This kind of repair works requires more resources than the works do at the shipyard.

Failure of Performance

The representative items of guaranteed performances for FLNG are presented in Table. 1.

The performance test is the job to check that FLNG is operable with the guaranteed performance. The control logics of facilities or the hardware of facilities are modified during the performance test in order to get the guaranteed performance. Generally, the production rate of condensate, the power consumption and the performance of individual process/utility unit show the guaranteed performance easily. And, much time is not required to reach the guaranteed performance after the start-up. So the impact of modification works on this kind of facilities could be negligible. In contrast, the system related to the production of LNG and LPG is based on the complex liquefaction technologies. So much time is required to get the guaranteed performance. If the guaranteed performance is not made with the current condition, many resources including manpower, cost and facilities are injected at the site location. In addition to this, in case of FLNG, the liquefaction process is major process of FLNG and that process uses most power of FLNG. So, the modification of liquefaction process can cause the modification of power generation system and other utilities. The failure of liquefaction module is a major risk of FLNG's commissioning.

Table. 2 – Acceptable dimension of vessel for Korean terminals

Items		Incheon		Pyeongtaek		Tongyoung		Gwangyang
		No.1	No.2	No.1	No.2	No.1	No.2	No.1
Main Alongside		P&S	P&S	P&S	P&S	P	P	P
Water depth(m)		14.0	14.0	14.0	14.0	14.0	14.0	14.0
Tide level	High(m)	9.84	9.27	9.90	9.90	2.21	2.21	4.46
	Low(m)	-1.01	1.00	-1.00	-1.00	0.00	0.00	0.32
Acceptable vessel at terminal	LOA(m)	290.0	350.0	290.0	350.0	300.0	350.0	300.0
	Beam(m)	49.0	55.0	50.0	50.0	49.0	55.0	46.0
	Draft(m)	12.5	12.5	12.5	12.5	12.5	12.5	11.5
	Disp.(mt)	100,000	177,390	105,000	177,380	110,000	177,380	113,900
	Cargo(m^3)	No info.	270,000	165,000	270,000	165,000	270,000	165,000

Table .3 – Dimensions of FLNG based on the reference projects

Items	FLNG 1	FLNG 2	FLNG 3	FLNG 4
LOA(m)	488.8	393	338	439
Beam(m)	74.0	64	62	65
Draft(m)	19.1	15	15	17

2.3 Solution

The risks mentioned earlier are resolved by maximizing the commissioning works at the near shipyard. To execute the commissioning works for the LNG containment system and liquefaction plant at the near shipyard, the natural gas and LNG are required at the near shipyard. First of all, LNG needs to be loaded in LNG cargo containment system with the appropriate method for the test of LNG containment system. And then if the suitable system to generate natural gas from LNG is considered on the early stage of project, the performance test for liquefaction plant of FLNG could be carried out with the natural gas generated from LNG in LNG containment system. In this chapter, the feasible and optimized solutions are explained.

Bunkering

The three different solutions to load LNG into FLNG's LNG containment system in the sea near shipyard are found in order to execute gas trial. First, as same as typical LNG carrier, FLNG is towed by the tug boats to the LNG terminal and received LNG which is required for the gas trial. This method requires the several conditions. The vessel without the own propulsion system cannot access to the LNG terminal commonly as per the check list of International Safety Guide for Oil Tanker and Terminal(ISGOTT) which is published by OCIMF(Oil Companies International Marine Forum). If the manager of terminal and the port administration allow, the vessel can access to the LNG terminal without the own propulsion system. In addition to the permission, the dimension of vessel which can access to the jetty of LNG terminal is limited as presented in Table. 2. The design of LNG terminal is based on the dimension of general LNG carriers. The dimension of FLNG is not suitable to access to the LNG terminals normally. The examples for dimension of FLNG are presented in Table. 3 based on the references. As a result of comparison between the dimensions of FLNG and one of acceptable vessel at terminals, it is impossible to tow FLNG to LNG terminal for LNG loading because the dimension of FLNG is not suitable to tow LNG terminal. The second method to load LNG into FLNG is transferring LNG from LNG carrier to FLNG with the side by side method in the sea near shipyard. This method is impossible because the side by side method requires that one of the two vessels has to be secured to keep the position during the transferring operation in the sea but there is no way to fix FLNG or LNG carrier itself in the sea. Generally, FLNG is secured by the turret mooring at the site location and the thrusters are used for the weather vaning.

The last method is that LNG bunkering vessel transfers LNG to FLNG moored to the quayside of shipyard. With this method, FLNG receives LNG from LNG bunkering vessel stably because the position of FLNG is kept. Actually, this method is not available at the shipyard due to the Korean law at present. But, this kind of method is already used to supply LNG to LNG fuelled vessel in the European sea. And, the Korean government is preparing the amendment of law which is related to the bunkering operation near shore. Taking these conditions into consideration, in the near future, transferring LNG to FLNG could be executed by the bunkering method at the quayside of shipyard. After loading LNG from the bunkering vessel, FLNG is towed to the international waters near the shipyard for the gas trial as same as normal LNG carriers.

Table. 4 – Required gas to operate the liquefaction module

Purpose	Required Gas Quantity	Temp. & Pressure
Liquefaction	412 ton/h	20℃, 82 barg
Fuel gas for Gas turbines	42 ton/h	N/A

Table. 5 – Method to generate the gas for test

Case	Primary heating source	Secondary heating source
1	Sea water from dedicated system	N/A
2	FLNG's heating source (Hot water/Steam etc.)	N/A
3	Propane	Sea water from FLNG's system
4	Glycol water	FLNG's heating source (Hot water/Steam etc.)
5	FLNG's cooling water (Fresh water)	Sea water from FLNG's system

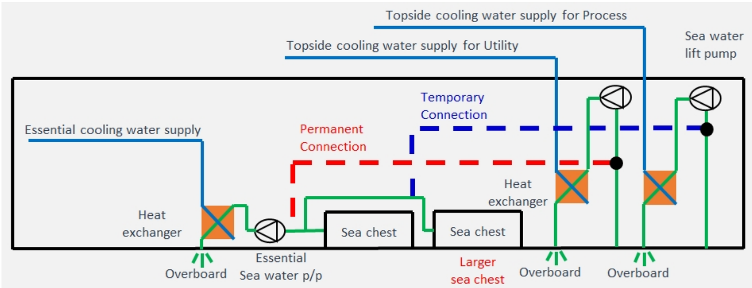

Fig. 4. – Conceptual drawing of FLNG's cooling water system

Liquefaction plant test

The detailed design of FLNG is changed as per the liquefaction processes but generally, the liquefaction module of FLNG requires the large compressors to pressurize the nitrogen gas or the mixed refrigerants which are used as coolant for liquefaction process. The prime movers for the compressors are various but the main energy source for FLNG is the fuel gas which is separated from the feed fluid. So, the gas for liquefaction and fuel of FLNG is required for the performance test of liquefaction plant. To supply a gas, the basic concept is vaporizing LNG in the storage tanks and delivering the generated gas to the facilities for the operation of facilities. The various kinds of heating sources could be used to vaporize LNG. For example, the LNG could be vaporized by the hot water and hot oil which are used as a common heating medium for FLNG or the sea water could be used to transfer directly the heat to LNG to be vaporized. To find the optimized process to generate the pressurized gas, the commercial process simulation program, HYSYS 8.3 is used to evaluate the many cases in an efficiency point of view. In addition to the process simulation, the pros and cons of each case are analysed and compared. The required quantity and condition of gas to operate the liquefaction module are shown in Table. 4 for FLNG which of the production capacity is from 2.5 to 3.0 mtpa(Million Tons Per Annum).

The five cases to generate the high pressurized gas are selected to evaluate as below Table. 5. The primary heating source is a heating medium to transfer a heat to LNG and the secondary heating source is a heating medium to transfer a heat to the primary heating source. If the two heating sources are used to heat something, the heating method is categorized as an indirect heating method. In another case, the heating method is a direct heating method. As a result of process simulation, the case 1 shows most effective among the five cases because the direct heating method is more efficient than the indirect heating method and no heating is required to heat up the sea water due to the direct overboard of sea water. The main components of gasification unit are the vaporizer, the high pressure LNG feed pump and so on. But, the case 1 requires this kind of equipment besides the equipment to supply the sea water to the gasification unit such as the sea water lift pumps and the large bore piping. The additional components cause the additional CAPEX(Capital expenditures) and require the space to install the components. In case of the case 5 which is placed the second efficiency process in the process simulation, the components besides the basic component to vaporize LNG are already installed on FLNG. So, the additional CAPEX is lower than the case 1 and the additional space is not required. Other cases are not considered because those are placed bottom in the process simulation and the additional component is required to use the special heating medium such as the propane or glycol water. As a result of analysis, the case 5 is selected as the optimized process for the gasification unit.

In the case 5, the cooling water system of FLNG is used to supply a heat to vaporize LNG and the fresh water of cooling water system is cooled by the sea water lift system of FLNG. So, the sea water lift system needs to be operable at the quay of shipyard without long sea water intake risers under the bottom of FLNG. To achieve this condition, the suction side of sea water lift system is connected to the suction side of sea chest which is installed to supply the sea water to the essential cooling water system. The sea water is supplied to the sea water lift system via the sea chest with this solution. The concept of this solution is shown in Fig. 4. The temperature of sea water will be different from a design basis and that will be higher than the planned temperature. But, the sea water is used to give a heat for cooling fresh water and therefore the temperature does not become a problem for this solution. Also, the test could be executed during winter in Korea when the temperature of sea water is similar to a design temperature of sea water lifting system.

3. Conclusions

To achieve the efficient commissioning works, the commissioning activities before the towing to the site location shall be maximized as much as possible. The risks of commissioning works at site location could be minimized with this approach. In case of FLNG, the integrity of LNG containment system and the performance of liquefaction module are main risks of the commissioning works at the site location. But, this kind of risks could be relieved by some technologies which are described in the body of this paper. The summary of proposal based on technologies is presented in Fig. 5. According to the sequence, LNG shall be transferred stably by bunkering method from LNG bunkering vessel to LNG containment system of FLNG. And then LNG in LNG containment system shall be vapourised by the temporary regasification unit which is using in-direct heating method as per the result of analysis of this paper. The secondary heating source is the sea water from sea water lifting system of FLNG and the primary heating source is cooling fresh water of FLNG. The vapourised gas shall be used as the fuel for gas turbines of main power generation and refrigerant compressors. Also, the liquefaction plant shall liquefy the vapourised gas for performance test of plant. For the operation of whole commissioning activities, the sea water lifting system shall be operable with the connections to the sea chest at the quayside of shipyard.

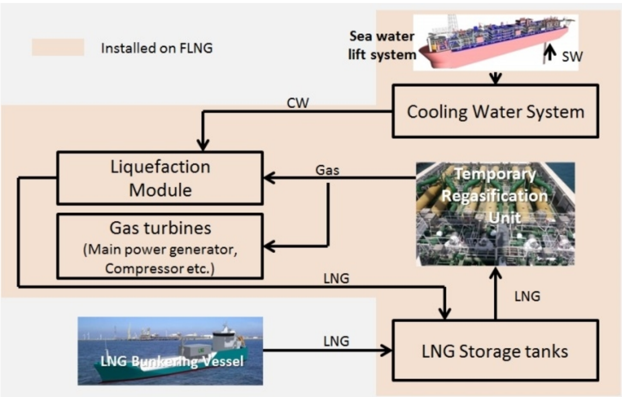

Fig. 5 Concept of maximizing commisioning works at the shipyard

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