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A Study on conceptual design of mini FSRU as LNG receiving facility

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Abstract. One of prioritizes of the government of Indonesia is to provide electricity in Papua regions to reduce electricity disparity in Indonesia. According to recent Power Supply Business Plan of PT Perusahaan Listrik Negara (Persero), there are more than 50 power plants are planned to build in Papua and Maluku regions. One of power plants which has considerable high capacity is located in Jayapura, Papua Province. This study addresses the conceptual design for three power plants in this area with capacities of 50 MW, 50 MW and 40 MW. The power plants are assumed to be supplied by natural gas from Floating Storage and Regasification Unit (FSRU). This concept was chosen because of the sloping contour of the seabed and to reduce the use of land for the receiving terminal. To supply the FSRU, a 30,000 m^3 small scale LNG vessel is used for a shuttle vessel with estimated roundtrip is 15 days. The conceptual design consists of determination of cargo tank capacity, designing lines plan and general arrangement of FSRU, stability calculation, Process Flow Diagram (PFD), Process and Instrumentation Diagram (P&ID) for loading and regasification processes at the FSRU.

1. Introduction

The electricity demand in Indonesia has increased every year. According to power supply business plan of PT. PLN (persero), the increase in electricity demand reaches 8.1% per year [1]. For this reason, the Indonesian government planned to provide 35,000 MW of electricity, mainly in areas that are still shortage of electricity. To fulfill this plan, the government purposed to build a power plant and upgrade the existing power plant. As in Papua, it has been planned to make several power plants in Jayapura. The power plant in Jayapura region consists of three power plants with the capacities of Jayapura Main Power Plant (MPP) 50 MW, Jayapura Peaker Power Plant 50 MW, and Jayapura Load Follower Power Plant 40 MW. These three power plants are designed to be supplied by LNG as their main fuel. An LNG shuttle vessel with a size of 30,000 m^3 is used to supply the receiving terminal with estimated roundtrip is 15 days. To be able to receive LNG, it requires a facility that can store, process and distribute LNG to the plant.

The LNG receiving terminal is a facility required before supplying gas to the power plant. In general, this receiving terminal consists of a storage unit, a processing unit for LNG regasification and an LNG distribution unit to the plant. There are several alternatives of LNG receiving terminals that can be used such as offshore based, onshore based or a combination of both. Onshore based is a land receiving terminal where all storage tanks and regasification units are located on land. Offshore based when the floating structure is used while all the storage, regasification and other systems is inside the floating structure. Some types of offshore receiving terminals are Floating Storage Regasification Unit (FSRU), Floating Storage Unit (FSU) and Floating Regasification Unit (FRU). FSRU is a unit that can work alone, while FSU and FRU can be combined with onshore receiving terminals.

The selection of this terminal cannot be done arbitrarily. Terminal selection refers to the advantages in both technical and economic aspects. In this study the type of receiving terminal in the form of FSRU was chosen to supply power plants in Jayapura. The FSRU was chosen because of the sloping contour of the seabed and the area is not available to build a land terminal. In determining the proper FSRU design, it requires various considerations, both technical and economic aspect. This paper discusses the technical considerations of building an LNG terminal in supplying LNG to the Jayapura power plant. Conceptual design consists of general arrangement design, system design, 3D design, and stability analysis in accordance with IMO regulations. General Arrangement is the determination of the main dimensions of the ship and the arrangement of components and equipments on the ship that refers to DNV GL. The systems designed are in the form of Process Flow Diagrams (PFD), and Process and instrumentation Diagrams (P&ID) of the loading system and regasification system. To achieve this, a special methodology and calculation are needed to determine the specific specifications of the entire equipment. Determining the LNG needs of each plant to know the total needs of the LNG for 15 days, so that the specifications of the tank can be determined.

2. Literature Study

LNG is a clean energy and relatively safe compared to other fuels such as gasoline and diesel oil because the flammable temperature of the LNG is relatively higher. When the LNG tank is leaked, LNG will instantly vaporize and move upwards due to the mass of natural gas is lighter than the surrounding air [2]. Basic information about LNG and its properties are needed to be considered in order to determine how LNG processing equipment can work.

FSRU is one option that can be considered as a receiving terminal when the onshore based receiving terminal more difficult to build in certain area due to lack of are onshore to install the facilities. The study revealed that the LNG facilities in form of FSRU has price around 50-60% of the onshore terminal price [3]. Capital expenditures for FSRU may be lower than onshore, due to the potential efficiency of construction costs, through repeated acquisition (iteration of the design) where there is a generic design concept, with minor adaptation for each particular project. [4]

The construction times of FSRU about half than that of the onshore terminal LNG and other advantage of FSRU is that this facility can be moved to other location when necessarily required. The selection process of the type of LNG receiving terminals can be found in the study entitled "Study of Selection Technology LNG Receiving Terminal for Bali Island (case study of LNG supply from Tangguh LNG Plant to Bali)"[5]. There are several criteria used in the selection process such as: land area, safety aspect to surrounding residential and working areas, and implementation period. In their study, combination of Floating Storage Unit (FSU) and Floating Regasification Unit (FRU) were selected as LNG receiving terminals in Benoa Bali over other two alternatives namely Gravity Based Structure and land based receiving terminal.

Previous study on LNG distribution in Papua region can be found in Antara, G.B [6]. In the study, the LNG distribution is done using two LNG ships with the capacity of 10,000 m3 and 23,000 m3 and onshore based terminal LNG receiving facilities is considered to be used in Jayapura. However, this study considers an offshore based terminal by means of FSRU while FSRU is supplied by LNG shuttle carrier which has 30,000 m3 in capacity.

3. Several Consideration on Designing FSRU Facility in Jayapura

Mobile Power Plant (MPP) Jayapura is located in the Holtekamp, North Jayapura, as well as two other power plants that have been planned to be construct and operated near to MPP. These power plant are

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located quite close to the coastal area, but in a position on the edge of a bay where the sea level is very shallow. The position of the power plant can be seen in Figure 1.

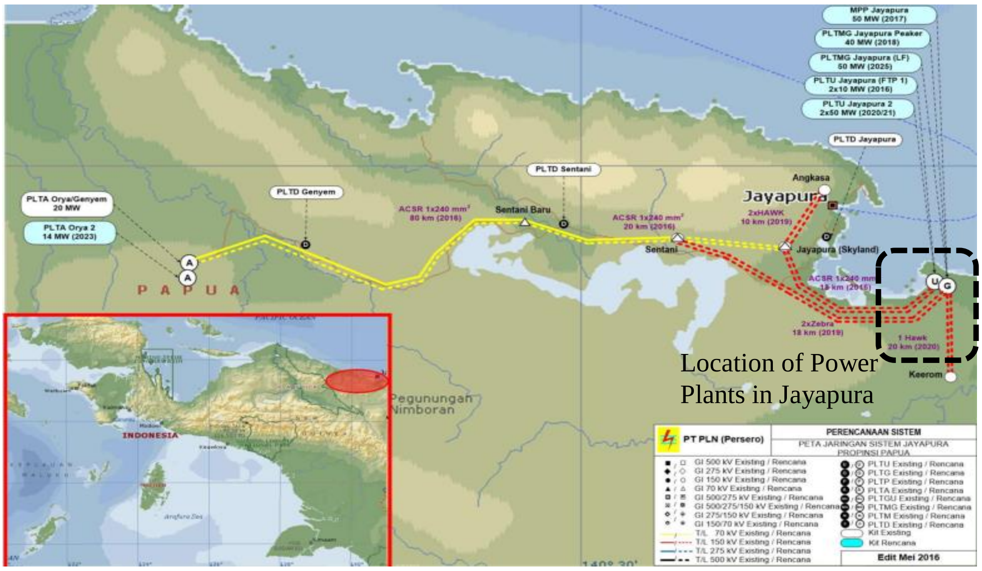

Figure 1. Location of Power Plants in Jayapura Region [1]

The selection of dimension of FSRU highly depends on demand as well as the location including the water depth in the location. Other consideration of locating FSRU is dimension of the available shuttle vessel in such away the shuttle vessel can be moored directly to the FSRU or by means of intermediate jetty facility. The shuttle vessel must be able to supply the FSRU in close proximity so that the condition remains safe. The shuttle vessel that consider in this study has a draft of 7.4 m, hence the location to allow certain draft to be served when the jetty is located approximately 1500 m away from shoreline. Total length of trestle including in the shore approach is 1,910 m, where the distribution pipeline will be stretched along this length. The location and length of jetty as location of FSRU can be seen in Figure 2. This figure also give some information regarding to condition of water area i.e. the bathymetry conditions.

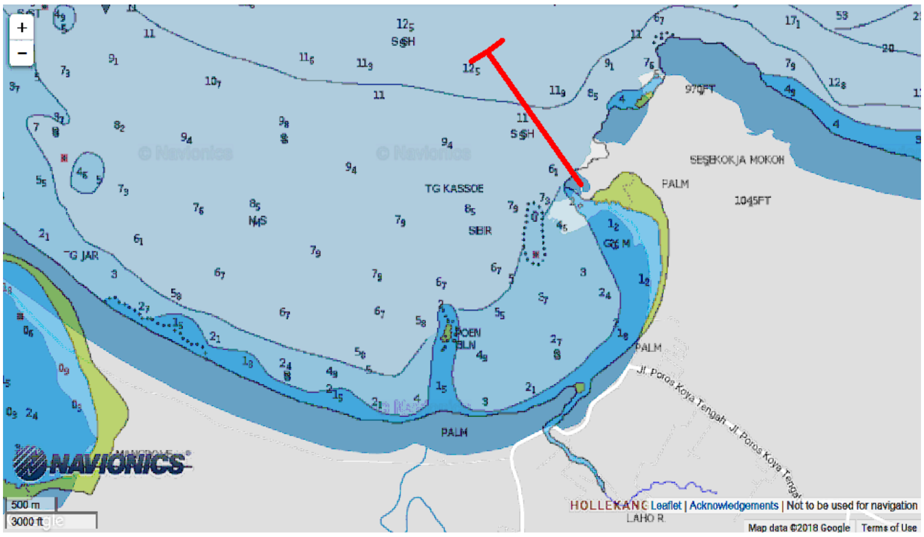

Figure 2. Bathymery and Recommendation of FSRU Location [7]

According to the duration of roundtrip of shuttle vessel to deliver LNG to Jayapura from supply location, the minimum capacity of LNG containments in FSRU must able to save an LNG for 15 days or about 10,365 m^3. Four type C tanks with each capacity of 3,750 m^3 are installed in the FSRU. Type C tank is an independent tank that can withstand greater pressure, so the formation time of the boil-off gas (BOG) is longer. This tank is also considered to be more efficient in overcoming the sloshing effect of liquid loads. Local stress also does not occur in some parts, when it is given more force, so that the tank is safer even though the condition is not full.

In selecting the volume of the tank also through several considerations that the tank cannot be fully filled 100% or emptied until 0%. Referring to DNV Part 5 [8], the maximum volume can be filled at 98% of the total tank volume. Thas is done to prepare the space when BOG is formed, then there is no overpressure inside the tank. While the minimum volume that must be contained in the tank is 5% of total tank volume. This is done to keep the low temperature inside the tank and prevent thermal shock due to extreme temperature differences during tank filling.

4. Conceptual Design of FSRU Facility in Jayapura

Basically, the barge type of FSRU is considered in this study. The principal dimension of the FSRU is determined through various stages of configuration so the result is an appropriate ratio between length, draft and breadth. This configuration is done iteratively so that the dimensions of the FSRU and area for putting all of required components on the barge can be optimized. The most suitable configuration is obtained by adopting and referring to Damen Stan-Pontoon B32 SPo9832 [9]. The principal dimension of FRSU barge to be built as receiving terminal in Jayapura as follows: length overall (LOA) 97.5 m, Breadth 32.2 m and Height 8.1 m.

To design and determining number of required compartment and room space in the FSRU, it is necessary to calculate frame spacing and determine the location of watertight bulkhead on the ship. Referring to DNV GL [10], the double bottom height is 1.6 m. In accordance with the length of the ship and the location of the engine room at the aft side of the ship, the FSRU must have at least four watertight bulkheads. The bulkheads include collision bulkhead, after peak bulkhead, engine room bulkhead, and bulkhead in the cargo area. Hence, the arrangement of the tanks on the FSRU is given in Figure 3.

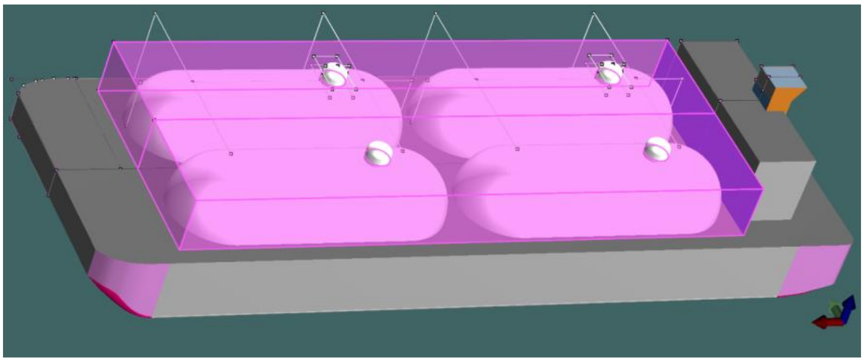

Figure 3. Configuration of the LNG Tank, Compartment, Superstructure and Deck Houses

LNG loading header is a pipe used to drain LNG from the manifold to the LNG tank. LNG loading process uses a pump from shuttle vessel with capacity of 550 m^3/h. Hence, the transfer process can be done in at least 5 hours. Condition inside the pipe must be kept at an allowable speed to avoid electron displacement. According to DNV [8], the thickness of pipe is 4.19 mm with internal diameter of 264.62 mm.

The regasification process starts from pumping the LNG to the LNG header that will be distributed through two different lines. High pressure line which serves to supply natural gas demand at MPP Jayapura, while low pressure line supplies the needs of Jayapura peaker and Jayapura load follower power plant. The spesification of high pressure and low pressure lines is the same with 5.54 mm in thickness and internal diameter of 598.52 mm. Figure 4 shows that after the LNG pump output there is a flow meter that will automatically open the valve when the LNG flow is considerably very low. It will connect to the return pipe that make LNG flow back to the tank, this happens at the time of starting the pumps. LNG flows toward two lines which is on the high pressure line is given the high pressure pump to increase the pressure. High pressure pump is chosen instead because its dimensions, weight and power tends to be smaller than putting a high pressure compressor before the metering unit.

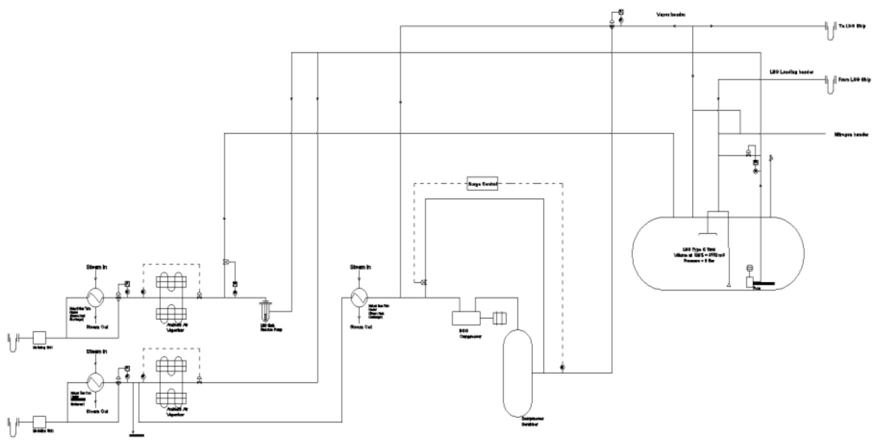

Figure 4. Process Flow Diagram of FSRU

LNG in the tank will certainly change to gas phase due to receiving heat from its surroundings. Therefore, the gas formed is allocated to the needs of generator and boiler at FSRU. If the gas formed exceeds its need, then the gas would be channeled toward the low pressure line by BOG compressor. The BOG compressor equipped with supporting facilities such as anti-surging and scrubber. That equipment aims to keep the BOG compressor operate in secure conditions. If the gas flow is reduced then the BOG compressor will receive back pressure which is very dangerous for the compressor's life time. To prevent this condition, anti-surging is installed and serves to drain the compressed gas to the suction line of compressor. In the other hand, pressure differences will forming droplets and when these droplets flowing directly towards the BOG compressor, this condition will impact to the life time of compressor. A gas scrubber is installed to help separation of the droplets with the gas. BOG heater is installed as it is needed to increase the temperature when the temperature of the gas coming out of the compressor is low. The BOG heater used two pieces of Thermax TVN Automatic Direct Steam Vaporizer T25S which having maximum capacity 25 SCFH [11].

Figure 5 shows an arrangement of regasification facilities that is located on the fore side of FSRU. The regasification facilities designed at FSRU are Ambient Air Vaporizers (AAV), heater and pumps. This designed was referred to other study found in [12] that the AAV is ranked number two, one level above an open rack vaporizer (ORV). This AAV also appropriate to be operated at ambient temperature above 18^{o}C. The same specification of AAV is fitted for the low pressure and high pressure lines. The AAV installed is Thermafin Supergap with having maximum capacity of LNG is 77 m^3/h and temperature output is 10^{o}C at ambient temperatur of 20^{o}C [11].

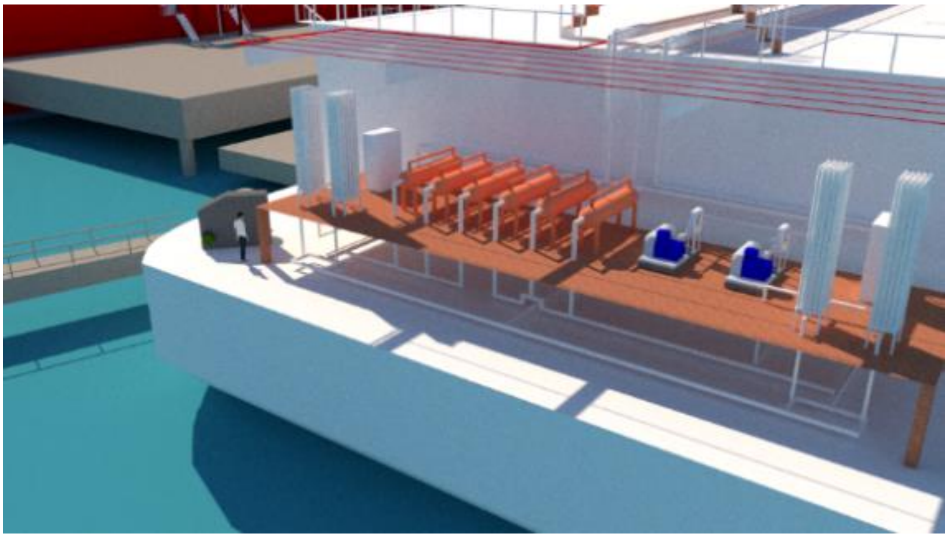

Figure 5. The Arrangement of Regasification Facilities in FSRU Jayapura

Stability analysis is considered for two conditions, at empty load condition (about 5% load and holds ballast) and full load condition (minimum 76% load). While in both condition, it is assumed that fuel oil, lubricating oil, and fresh water are in full condition. The Jayapura FSRU's stability booklet is calculated based on the Internasional Maritime Organization (IMO) regulation that should be applied for all ships [13]. The stability booklet according to "Trim & Stability Booklet" [14] at the Jayapura FSRU is as follows:

Table 1. Stability Booklet

Condition		Unit	1 Empty Load Condition	2 Full Load Condition
Light Weight		(t)	5805.05	5805.05
Fuel Oil		(t)	97.68	97.68
Lube Oil		(t)	1.259	1.259
Ballast Water		(t)	3882.78	0
Fresh Water		(t)	6.183	6.183
Displacement		(t)	9791	14262
Draft	fore	(m)	3.336	5.037
	aft	(m)	3.11	4.207
	mean	(m)	3.223	4.622
Trim		(m)	0.83	0.48
T.P.C		(t)	32.081	32.081
M.T.C		(m)	254.37	248.92
K.G		(m)	5.645	4.378
G.M		(m)	16.05	25.199
Stability	Judgment		Good	Good
	Area 0-30	(m-deg)	159	131
	Area 30-θ u	(m-deg)	76,4	58,6
	Area 0-40 θ u	(m-deg)	235	189.9
	Max GZ	(m)	7.704	5.9

Table 1 shows that stability condition of FSRU can be considered good or acceptable that all condition comply with the IMO regulations. It can be seen that the righting arm (GZ) in the condition of empty load is greater than the condition of full load, this means that maximum heeling occurs in an empty condition is greater than the full condition.

5. Conclusion
The conceptual design of FSRU that will be used to serve power plants in Jayapuran has been shown. Several aspect in design also discussed such as determining principal dimension, general arrangement of FSRU, arrangement of loading of LNG as well as regasification unit and unloading of gas to power plants. To assure the stability of the FSRU, the stability analysis also conducted and discussed in this paper.

6. Future Direction of Research
Future research has been prepared to complete this existing research. Further research aims to measure the safety level of the system that has been made. The research is in the form of risk assessment to the loading system and LNG regasification system. This risk assessment is carried out considering the operation of the FSRU in an open space using equipment that generates heat. In addition, with a working fluid is kind of flammable gases, it is very possible if a fire can occur during the operations. In general following steps will be conducted for the risk assessment: (1) hazard identifications, (2) frequency analysis, (3) consequence analysis, (4) risk representation and (5) propose mitigation if necessary.

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