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Simulation Modeling of Rounded-Shape Floating LNG Production and Storage Capacities

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ABSTRACT

Liquefied Natural Gas production processes involve many high profile control systems and equipments that costing a vast amount of investment. Any mistakes in the management decision to select the resources and equipments will cause serious problem aftermath and it will be difficult to meet the expected output. Production processes play very important rules in Liquefied Natural Gas Supply Chain and integration with well models (under water process), storage models, transportation model and receiving terminal models. The main focuses of this paper are to simulate production and storage capacities of Rounded-Shape Floating Liquefied Natural Gas by considering the capacity of every single process and utilization of equipments used and storage design. Simulation modeling can be used as controlling and decision making tool with associated factors such as Front-End Engineering Design rate, capacity of every process and storage design capacity.

KEY WORDS: *Simulation Modeling; Liquefied Natural Gas; Rounded-Shape Floating Liquefied Natural Gas; Production and Storage Capacities*.

NOMENCLATURE

LNG	Liquefied Natural Gas
$FEED$	Front-End Engineering Design
$FLNG$	Floating Liquefied Natural Gas

1.0 INTRODUCTION

Today, demand of Liquefied Natural Gas (LNG) is increased due to demand of natural resources from oil cannot meet the demand requirement. Natural gas as an energy source is increasing importance as the world's demand is expected to increase by 53% between 2008 and 2035 (EIA, 2011). As a consequence of the increasing market for LNG and uncertainty demand, the supply chain management has become more complex and the need for decision support has become even more evident.

Consideration of real tactical supply chain optimization issues for LNG including the production volumes, liquefaction, transportation, storage, regasification and sale volumes are very important for the decision making. Supply chain management is defined as a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores so that merchandise is produced and distributed at the right quantities, at the right locations, at the right time, in order to minimize system-wide costs while satisfying service level requirements (D. Simchi-Levi, 2000). In LNG supply chain, there is difference supply chain flow between conventional and floating LNG supply chain. For conventional supply chain the supply from offshore to onshore using pipeline however for FLNG all the liquefaction process are done on the vessel before transporting to degasifications receiving terminal. Therefore for FLNG supply chain, it is required very careful capacity calculation at production process stage in order to get higher utilization of facilities and smooth supply chain process to meet the expected output.

In general, a simulation can be defined as the process of designing a mathematical logical model of a real system and experimenting with this model on a computer. Simulation allows the user to monitor the dynamics of a system under various conditions and provides its users with an understanding of the system being modeled.

Simulation also gives organizations the much-needed ability to ask "what-if?" when making strategic and operational decisions. It also gives users a low cost in doing experiment and safe environment in which to experiment with different strategic scenarios. As a result, decision-makers can be sure and more confidence that they have found the solution that is most fit for their organization before running the project. Benefits of supply chain using simulation modelling are numerous including improved throughput, reduced costs and lead-times and better utilization of resources before the actual project is done.

The interaction among factors such as upstream, production process equipments, storage, transportation and receiver are extremely complex and difficult to obtain balancing without using simulation. Simulation process provides invaluable insight into where unforeseen constrains and bottlenecks lie. The results of simulation modeling have been applied successfully for over a decade to help organization meet their long term strategic production goal. Simulation modeling has been used to optimize pipelines, storage, and the export facilities required to accommodate additional production capacity: to plan capital projects in anticipation of demand.

This paper intended to use simulation modeling to optimize the Rounded-Shape FLNG production and storage capacity and utility of equipments in every single stage in production to achieve high performance and profitability.

The rest of this paper is structured as follows, in section 2, we describe methodology used in this study followed by section 3 about result and discussion and finally in section 4 we draw some conclusion.

1.1 Overview of Liquefied Natural Gas (LNG) Market and its Contracts

When coordinating decisions along the LNG-value chain one cannot just deal with the routing of vessels and the fulfillment of the contracts, but have to look into how to produce LNG, the storage capacity and liquefaction facilities (upstream) and the re-gasification process. All the process has very closed integration each others in doing operation. Most of the LNG is traded in long term contracts without publicly known prices. NG prices in Asia are commonly linked to Japanese import prices for crude oil using a price-formula which has a variable component to protect sellers from low oil-prices and buyers from high oil-prices. During the last few years some of the long-term contracts have ended and been replaced with more flexible contracts. Nonetheless, the NG and the LNG are still priced against crude-oil (Holmes, C. 2007). To better deal with the risks associated with the high cost of constructing Rounded shaped FLNG plants, Storage capacity and transportation long term contracts with duration of 25-30 years are frequently used. To obtain optimal decision before signing the agreement, simulation modeling is one of the best approach can be used to predict future plan and make very confident decision.

1.2 LNG Exported and Imported by Countries in 2010

By the end of 2010, 18 countries were exporting their natural gas as LNG with the total exporter was 223.8 MMtpa. In addition, four countries – Belgium, Mexico, Spain and the US – were re-exporting LNG imported from another source. Qatar is by far the largest LNG exporter. In 2010, the country supplied 57.5 MMtpa of LNG to the market – more than one quarter (26%) of global supply – and its LNG exports will continue to grow as the mega-trains realize full-year production. Pacific Basin countries, namely Indonesia, Malaysia and Australia, are the next largest exporters and together accounted for 29% of the world's LNG supply in 2010

Japan has traditionally been the largest consumer of LNG and remains so today with an annual consumption of 71 MMtpa of LNG in 2010, followed by South Korea at 34 MMtpa. Together, these two countries account for just less than half (47%) of the world's LNG consumption.

1.3 Optimizing Rounded Shape FLNG Supply Chain using Simulation Modeling

The attention is turning to the potential of exploiting stranded offshore gas field using floating production, liquefaction, storage and offloading vessels – floating LNG is increased due to high demand and plenty of new small potential Natural resources available in deep sea. FLNG represents a fast-track route to obtain remote gas reserves which will help to bridge the expected supply shortfall in worldwide. The process of Rounded shape FLNG starting from under water production, Liquefaction, storage, transportation and receiving terminal and distribution to customers. This process is different from conventional supply chain where the supply from offshore to onshore using pipelines.

2.0 METHODOLOGY

To achieve the study's objectives, simulation was then conducted using Software Witness. The procedures for the simulation study of supply chain management are as follows:

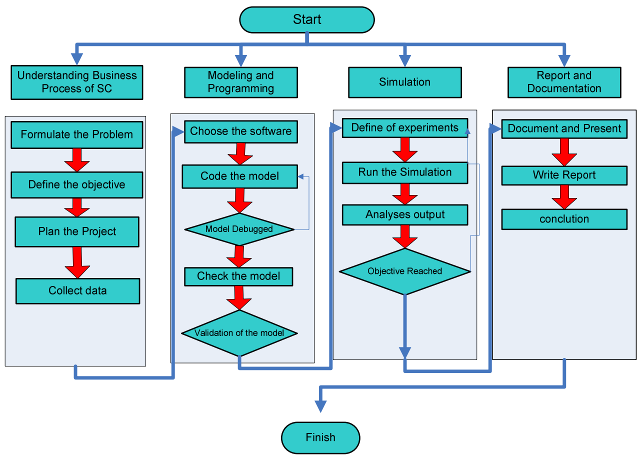

Figure.1: Research Methodology.

2.1 Rounded Shape FLNG Supply Chain

The FLNG supply chain may include the upstream legal and contractual regime governing the development and production of the gas field and the determination of the gas suppliers' production share (including applicable laws, granting instruments such as licenses and production sharing contracts (PSCs), and the inter-party equity allocation agreements such as joint operating agreements (JOAs). Indeed, it is likely that such upstream arrangements will be considered integral to the FLNG value chain because, except for LNG and NGLs, there is no other means by which the gas suppliers can market their gas. Further, downstream activities such as LNG regasification, gas storage, transportation (pipeline) and marketing arrangements may also form part of the FLNG value chain. Figure 2 display the LNG supply chain process:

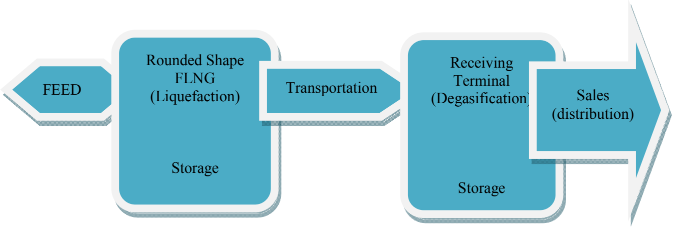

Figure.2: Rounded Shape FLNG Supply Chain

2.2 Formulate the Problem

The first step in developing a simulation model is to define the problem that must be addressed by the model. In this step, defining explicitly the objectives and the scope of the project are explained. In addition, boundaries must be defined between the problem of interest and the surrounding environment. It is important in this step define clearly the expected results of the simulation. In rounded shape FLNG the interaction among supply chain stages has to be considered furthermore for the capacity aspect and utility of equipment used in operation.

2.3 Simulation Rounded Shape FLNG Production and Storage

Gas companies, whether operating LNG or GTL plants, have a requirement to strike the right balance between overall plant availability (to provide a continuous supply of gas) and the capital costs associated with "redundant equipment." the overall performance of an offshore facility is a complex interaction between many factors including: capacity of each of stages in the process, list of stoppages for planned that can occur, Mean Time To Repair, Preventive maintenance and Storage capacity.

The Rounded Shaped FLNG will be moored directly above the natural gas field. It will route gas from the field to the facility via riser. When the gas reaches the facility, it will be processed to produce natural gas, LPG, and natural gas condensate as shown in Figure.3. The processed feed gas will be treated to remove impurities, and liquefied through freezing, before being stored in the hull.

The result of the capacity and interaction among process can be used to determine the balance of the overall stages, design optimal capacity of production and storage design for improving utilities of facilities and profitability as shown in Figure.4.

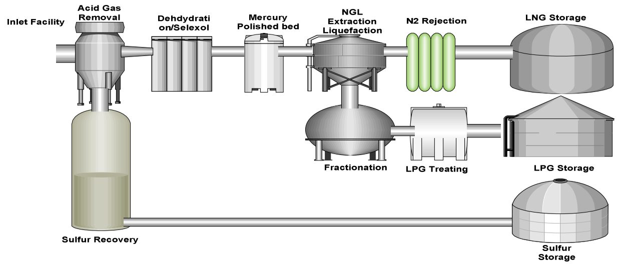

Figure.3: FLNG Production Process

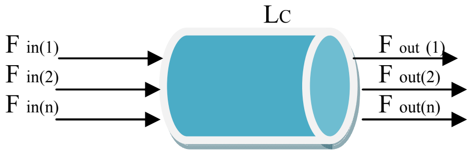

Figure.4: Basic Item

F in(n) : Flow into the object from another object
Fout(m) : Flow out of the object to another object
Lc : Current level in the object.

Note that pipelines and connectors are also treated as objects under this definition. The objects that we will define have the following properties:

- Input into objects: The input value are the amounts of material flowing out of the connect objects.
- Output from objects: The output values are the amounts of material that the objects connected to can accept Material level inside an object.

Continuity Equation
In the simulation, continuity equation is used as shown in Figure. 5. The total quantity of fluid passing through section

$$1-1 \;=\; \rho_1 A_1 V_1 \qquad (1)$$

The total quantity of fluid passing through section

$$2-2 \;=\; \rho_2 A_2 V_2 \qquad (2)$$

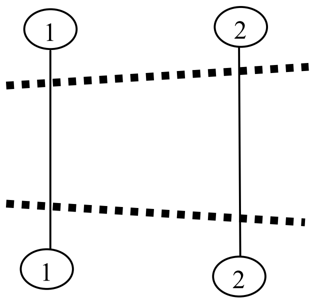

Figure.5: Fluid Flow through a pipe.

From the law of conservation of matter (theorem of continuity), we have

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2 \quad (3)$$

Equation (3) is applicable to the compressible as well as incompressible fluids, $\rho_1 = \rho_2$ and the continuity equation reduces to

$$A_1 V_1 = A_2 V_2 \quad (4)$$

In case of one –dimensional flow, mass per second $= \rho AV$, where; ρ = mass density, A= Area of cross-section, V= Velocity. Since the mass or mass per second is constant according to law of conservation of mass therefore, $\rho AV = constant$

Differentiation the above equation, we get

$$d(\rho AV) = 0 \text{ or } \rho d(AV) + AV d\rho = 0 \quad (5)$$

$$\rho(AdV + VdA) + AVd\rho = 0 \text{ or}$$
$$\rho AdV + \rho VdA + AVd\rho = 0 \quad (6)$$

Dividing both sides by ρAV , and rearranging we get

$$\frac{d\rho}{\rho} + \frac{dA}{A} + \frac{dV}{A} = 0 \quad (7)$$

2.4 Storage Capacity

New or expanding gas companies need to understand the true interactions between downstream shipping operations and production capacity and storage capacity. The FLNG production systems and lifting operations have stochastic events associated with them. In the production system, failures can occur. These can be caused by unplanned stoppages or as the result of knock-on effects from the offshore processing plant. In anticipating such a situation, company need to determine the optimal storage capacity by considering the design of Storage tank and the space of Rounded Shape LNG. Optimum storage capacity will avoid losing a lot of money and time for production and shipping operation.

2.5 Modeling and Programming

Develop a preliminary model either graphically (e.g., block diagrams) to define the components, descriptive variables, and interactions (logic) that constitute the system. This step includes the algorithms to be used to describe the system, impute required and output generated. The assumptions made about the system are documented in this phase and evaluate how there assumptions affect the accuracy of the model. The conceptual model includes a description of the amount of time, number of personnel and equipment assets that will require producing the model.

To model the LNG production Process, nowadays there is a large availability of discrete event simulation software each with some strengths and weaknesses. In it is possible to find the results of survey on the most widely used discrete event simulation software comparing 7 different software products according to 12 different criteria (A. Cimino, 2010). Witness is Lanner Group's simulation software package designed for both discrete event and continuous simulation of business processes. It can be linked with many common spreadsheet and database. The software provides its user with a scenario manager for the analysis of the simulation results.

2.6 Simulation

The use of simulation is the step where the model is used as experimental support to evaluate the dynamic behavior of the system. Of course, it is necessary to have defined the data on which will be able to act to achieve the goals that we set in the first stage. In the simulation stage, some scenarios were performed to obtain the optimum solution of the simulation. There 3 scenarios ware built in this study. The scenarios always based on the demand of LNG from the market.

- **Scenario A:**
  Scenario A showed uncertainty FEED output, Normal FLNG Production Process, full Storage
- **Scenario B**
  Scenario B showed Normal FEED output, abnormal FLNG Production Process, full Storage
- **Scenario C**
  Scenario C will show Normal FEED output, Normal FLNG Production Process, high storage capacity

3.0 RESULT AND DISCUSSION

The major objective in analyzing data are determining the performance of the system configuration and comparing alternative system configuration. Detailed analyses must be performed to extract long term trend and to quantify the answers to the driving question that motivate the construction of the simulation. During this process, statistical technique must be used to analyze the result of the model. In Addition during this step the modeler generate some graphic, tabular information in form that can be easily understood by diverse audience.

3.1 Output of Simulation

The LNG flow during the simulation run are recorded and used to calculate the statistics of plans fulfillment at the end of the simulation. These statistics as show the performance of every single stage in production process in the form of table and graph. In Figure 3 the appearance of processors capacity utilization for production process is displayed. The chart is used to understand the interaction between event and potential impacts on the system's performance. In the example shown in Figure.5, different color bars represent different percentage of processor performance. Inlet for instance, yellow describes the percentage time that fluid was flowing into the processor, green the percentage time that the processor spent processing fluid the blue describes percentage time that fluid was flowing out of the processor and pink describes the percentage time that the processor spent in an emptying state but no fluid was flowing out.

In the figure 6, the time utilization for storage is displayed in the form of Gantt chart. The pink color shows the percentage time that the processor spent in an empty state without fluid flowing in or out (not including time that the processor was empty but in a cleaning or repairing state).

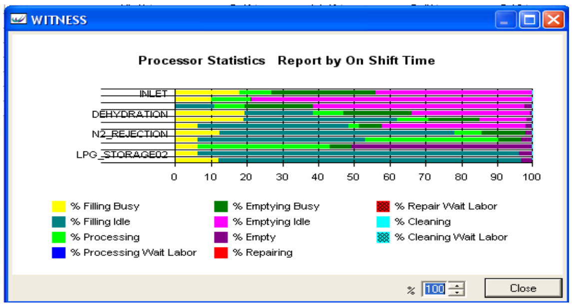

Figure.5: FLNG Production Process Performance.

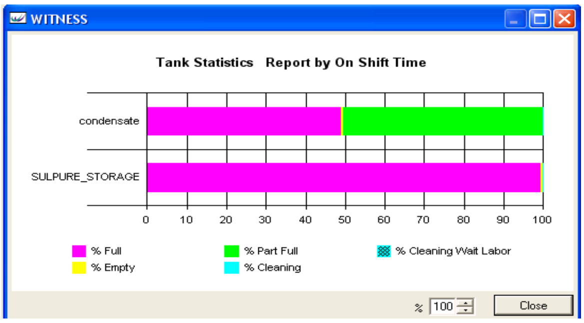

Figure.6: FLNG Storage Performance

Histograms shown in Figure.7 is typically used to show a particular aspect of performance varies and the range and shape of the variation. Histograms show the number of occurrences of values within defined ranges and are ideal for displaying time aspects of performance that are influenced by events which vary in frequency and duration. The example shows that the feed gas and feed gas 1 entered production process and some rejected from the process due to capacity constraint of production process equipment as shown in Figure.8. It is clearly shown that if the capacity of FEED gas is higher than capacity of production the utilization of the production equipments still can be upgraded by doing modification or change. Feed gas 2, feed gas 3 and feed gas 4 did not enter production due to the bulbs were switched off.

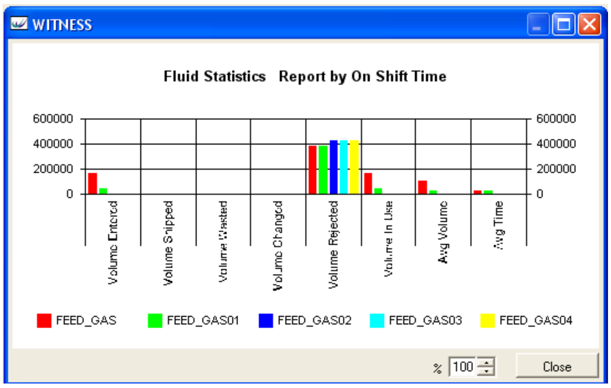

Figure.7: FLNG Feed Gas Output Performance

The comparison of selected scenarios output describe that by increasing the FEED output will increase the output for every single stage in production process and it also can increase the highest output among others scenarios.

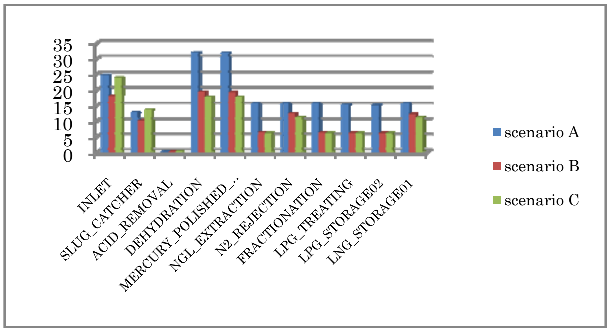

Figure.8 Comparison of selected scenario output

4.0 CONCLUSIONS

In FLNG supply chain, the integration of FEED, Liquefaction (FLNG production process), Storage and transportation play very important rule in achieving high performance and profitability. Optimum Production Capacity has been achieved in order to meet customer demand and profitability. By using simulation modeling individual or combination of stages in FLNG supply chain, such as clients are able fully understand the FLNG supply chain process and possible alternative better solution can be decided for short and long term decision. The results of the case study shown that the changes of production equipment capacity, design of storage can change all the process performance and result very significant output produced. This simulation can provide useful information for decision makers in every single stage to improve the productivity of all provided resources and facilities to meet the customer demand and profitability of the company.

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