Efficiency Assessment of LNG Supply Logistics to a Gas Network

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Abstract

This paper presents a model, that was developed for simulating the complex logistics of acquiring and delivering LNG, that utilize methane tankers with the purpose of feeding a gas network. The optimization of this logistics constitute a difficult task, considering the uncertainty involved with the reservoir levels of hydro power generation units and the gas demand profiles that will be required for thermo plants operation to prompt generate electricity. The gas demand profiles utilized for these simulations are hypothetical ones. The LNG logistics model was developed as an attempt to complement gas supply chain reliability models, that took several years to be developed by the authors, considering the importance of incorporating that critical issue to the optimization of the whole gas supply network performance.

Methane tankers are commonly used for transportation of LNG (Liquefied Natural Gas) that comes from various sources, with the purpose of supplying consumer's terminals. There are different types of loads, as for example: - Delivered At Terminal (DAT); and Free On Board (FOB). The LNG unloading schedule should be prepared, considering the objective of maximizing LNG delivery efficiency for the gas network, and, at the same time, of minimizing LNG carrier´s demurrage. These two goals are often conflicting and depend on the behaviour of several variables and parameters. The network performance was assessed, considering different demand scenarios, accounting for: the expected demand; the maximum demand; and a variable demand profile, according to 12 series, related to what is called - Long Term Average Demand (LTA) - that is estimated based 81 years of natural water flow historical provided to reservoirs of hydro power generation units.

It was also carried out a sensitivity analyses, through the variation of the following parameters: - the size of the empty space for berthing LNG carriers; the existence of additional storage capacity at the terminal; FOB and DAT LNG carrier's capacity; the number of FOB and DAT LNG carriers; and LNG discharge flow rates.

For different demand profiles, with evenly spaced unloading dates that should meet the average monthly demand, the gas supply efficiency may decrease and the demurrage, as well as the number of fillings may increase, if there is an increasing demand. For a defined demand profile, the demurrage is highly dependent on the LNG unloading schedule. If the demand is variable, according to the 12 series, the gas supply efficiency will decrease and the demurrage, as well as, the number of fillings will increase in comparison to the expected demand profile.

The reduction of the empty space - for berthing LNG carrier's - increases the gas supply efficiency, reduces the demurrage, but increases the number of fillings. The increase of LNG storage capacity increases the gas supply efficiency, decreases, slightly, the demurrage, and reduces the number of fillings. Increasing the number of vessels increases the gas supply efficiency, the demurrage and the number of fillings. The increase in the average volume of LNG carrier's increases the gas supply efficiency, the demurrage and the number of fillings. The increase in LNG discharge flow rates increases the gas supply efficiency, reduces the demurrage, but increases the number of fillings.

In order to increase the gas supply efficiency, reducing, at the same time, the demurrage and the number of fillings, the main parameters changes would be: to reduce the average volume of DAT loads;

to increase the volume of FOB loads and the number of DAT LNG carriers; and to provide additional LNG storage capacity.

1. INTRODUCTION

The LNG carriers specified with cargo type DAT (Delivered At Terminal) or DES (Delivered Ex Ship) is hired for certain periods of time (TCP Time Charter Party) and, in the contracts, there is a definition of the lay time. If the vessel stays for more time than it was previously agreed, due to the occurrence of possible problems in the terminal (as for example: - transfer flow restriction; lack of space; terminal or gas network failures; etc.) there will be a demurrage. In the other hand, ships specified with cargo type FOB (Free On Board) can be moored, as long as it is necessary.

The objective of this work was to evaluate, using a discrete event simulation model, the LNG supply logistics efficiency (Liquefied Natural Gas) for a gas supply network, considering expected demand scenarios, the maximum demand and a variable demand profile, according to 12 time series MLT (Long Term Average). In addition, sensitivity analyses were performed, varying the following model parameters: - the empty space for berthing LNG carriers; the existence of additional storage capacity; the capacity of LNG carriers; the number of LNG carriers; and LNG discharge rate.

The simulations were carried out, using the program TARO – Total Asset Review and Optimization [1]. The shipping functionality in TARO has been specifically developed to serve the needs of two industries:

- Crude Oil transportation industry
- LNG transportation industry

Typical objectives for TARO logistics studies are:

1) Assess the shipping system efficiency:
    a. Fleet optimization;
    b. Ship size optimization;
    c. Understand the key performance drivers for the shipping systems;
    d. Quantify demurrage time per ship/fleet;
    e. Determine the impacts of meteorological and oceanographic data and different thresholds for ships operation;
    f. Determine impacts of channel; daylight and traffic restrictions, etc.;
    g. Determine the maximum number of ships that can operate at a terminal before causing impacts to the performance.
2) Understand the behaviour of storage and berthing facilities:
    a. Optimization of the number of berths;
    b. Optimization of storage numbers and sizes;
    c. Assess the dynamic behaviour of the storage facility;
    d. Determine how storage and inventory can be shared by several parties and how this affects the operations;
    e. Assess the impacts of running more products through the same berth;
    f. Quantify the delays in berthing, queuing time, etc. and the key contributors;
    g. Understanding the reasons for berthing delays;
    h. Quantifying the number of interruptions in loading / unloading operations;
    i. Determine optimum berthing rules (when a ship should be cleared for berthing);
    j. Determine how daylight berthing restrictions would affect performance;
    k. Determine the impact of failures in the berthing and loading/unloading equipment on the system performance;
    l. Determine acceptance criteria for late cargos (when a cargo should be rejected);

m. Assess the impact of off spec LNG (evaluate if it could be exported, imported, blended, vaporized, etc.);

3) Understand and optimize the ship scheduling:
    a. Determine the feasibility of a given shipping schedule;
    b. Determine the minimum number of free slots to achieve a given flexibility and performance;
    c. Determine the impact of the interaction among various shippers, suppliers and on the onshore/offshore plants;
    d. Determine the impact of delays in ship arrival on overall operations.
4) Assess the performance of the integrated system:
    a. Assess the interrelations between: shipping, berthing facilities, scheduling, weather, reliability of the processing plant, production profiles, product demands, storage capacity, etc.;
    b. Assessing the impact of LPG and condensate export on the LNG production;
    c. Determine the relationship between design capacity vs. guaranteed liquefaction capacity.

2. PERFORMANCE INDICATORS

The following performance indicators were calculated for each one of the demand scenarios and sensitivity cases:

- Average efficiency of LNG gas supply to the network;
- Identification of the main contributors to losses of efficiency in the LNG gas delivery to the network (trip delays, berthing delays, terminals and gas network failures, etc.);
- Frequency and duration of interruptions of the LNG delivery to the network.
- Annual demurrage time per terminal and average demurrage time per load;
- Average number of times terminals are with minimal or full level of LNG; and the LNG storage level percentage distribution;
- Number of vessels used, number of loads and volumes delivered by LNG carriers.

3. SENSITIVITY CASES

For existing logistics problems and the requirements, considering the number of vessels, their respective load capacities and terminals storage capacities, sensitivity analyses were carried out with the following evaluating objectives:

1. Average efficiency of LNG delivery to the network and demurrage evaluation, as a function of the terminals empty spaces for berthing LNG carriers.
2. Average efficiency of LNG delivery to the network and demurrage evaluation, as a function of terminals additional storage capacity.
3. Average efficiency of LNG delivery to the network and demurrage evaluation, as a function of the load capacity of LNG carriers with cargo DAT.
4. Average efficiency of LNG delivery to the network and demurrage evaluation, as a function of the load capacity of LNG carriers with cargo FOB.
5. Average efficiency of LNG delivery to the network and demurrage evaluation, as a function of the number of LNG carriers with cargo DAT.
6. Average efficiency of LNG delivery to the network and demurrage evaluation, as a function of the number of LNG carriers with cargo FOB.

7. Evaluation of improvement measures by combining parameters in order to maximize the efficiency and to minimize the number of terminals filling and the demurrage.

4. CONCLUSIONS

Based on the results of the simulations, it can be concluded that:

1. For different demand profiles, with evenly spaced unloading dates in order to meet the average monthly demand, the gas supply efficiency decreases and the demurrage and the number of fillings increase with increasing demand.
2. For a defined demand profile, the demurrage is highly dependent on the LNG unloading schedule.
3. If the demand is variable according to the 12 series, the gas supply efficiency in relation to the expected demand decreases and the demurrage and the number of fillings increase.
4. The reduction of empty space for berthing LNG carrier's increases gas supply efficiency, reduces demurrage, but increases number of fillings.
5. The increase of LNG storage capacity increases gas supply efficiency, decreases slightly demurrage and reduces number fillings.
6. Increasing the number of vessels increases gas supply efficiency, demurrage and number of fillings.
7. The increase in the average volume of LNG carrier's increases gas supply efficiency, demurrage and number of fillings.
8. The increase in LNG discharge flow rate increases gas supply efficiency, reduces demurrage, but increases the number of fillings.
9. In order to increase gas supply efficiency, reducing at the same time demurrage and number of fillings, the main parameters changes would be the following:
    a. Reduce the average volume of DAT loads;
    b. Increase the volume of FOB loads;
    c. Increase the number of DAT LNG carriers;
    d. Provide additional LNG storage capacity.

5. REFERENCES

[1] DNV GL, *TARO – Total Asset Review and Optimization program*, version 4.04, 2012.