Improvement on plant thermal efficiency in MLNG Satu via MLNG Molecule Allocation Program (M-MAP)

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Abstract. It has always been an aspiration for a Liquefied Natural Gas (LNG) plant to be able to monetize natural gas to its design plant capacity and best plant efficiency. Being able to achieve design capacity means project investment is paid off, whereas operating at the best efficiency means operating cost is optimum. Malaysia LNG Sdn Bhd (MLNG SATU) is consistently operated at design nameplate capacity post MLNG Rejuvenation and Revamp (MRR) project in 2005. Existing process control and optimization program has been helping the plant to consistently achieve maximum plant capacity within constraints on operational target and equipment performance. MLNG Molecule Allocation Program (M-MAP) was developed in 2016 to improve current program by looking at the plant thermal efficiency aspect, defines as Process Efficiency (PE). Leveraging on good existing plant data acquisition system and effective process control and optimization program in MLNG SATU, M-MAP has successfully expanded from a simple engineering calculation to a program that enables MLNG SATU production to achieve at its best efficiency. Developed in bi-phases, the Phase 1 of M-MAP has improved the overall efficiency of MLNG SATU by 1.3%. The Phase 2 of the M-MAP is currently under implementation; expecting another step in the overall efficiency of MLNG SATU within 0.5%.

Keywords: steam turbine driven LNG plant, process efficiency, molecule allocation program.

1. Introduction

Malaysia LNG Sdn Bhd (MLNG SATU) is a sea cooling water, steam turbine driven LNG plant with annual LNG production of 8.4 metric tonne per annum (mtpa). MLNG SATU consists of three identical modules namely Module 1, 2 and 3. Each of modules in general can be divided into three main areas which are gas treatment, liquefaction and utilities.

MLNG SATU had its first online plant data acquisition system in 2002 which enables the users to monitor plant condition in real time basis. In 2008, the first process control and optimization program was in place in MLNG SATU covering optimization of liquefaction process, named “Main Cryogenic Heat Exchanger Advanced Process Control”. In 2013, the program was extended and includes a function that enables module selection and ability to maximize production of selected modules at minimum allowable feed gas pressure to the modules, named “Landing Pressure Automation”. The program also includes process optimization in gas treatment area.
In 2016, MLNG SATU explored on possibility to further maximize LNG for a given feed by improving plant efficiency. There is a great potential to further enhance the value from the existing LNG assets using new industrial internet of things (IIoT) and data analytics technology [2]. A program named MLNG SATU Molecule Allocation Program (M-MAP) was initiated with two objectives (a) to determine the best combination of production target between LNG modules that able to achieve high plant efficiency of MLNG SATU (b) to identify efficiency gap for each of the modules and factors contributed to the gap in order to allow for rectification towards improving plant efficiency. The program combines data analytics of plant efficiency using real-timed plant data with existing MLNG Satu Advanced Process Control.

To achieve these objectives, a performance indicator named; Process Efficiency (PE) is introduced in M-MAP. PE is defined as the ratio of energy of total useful products (in gigajoules) with energy of total feed (in gigajoules) (See Equation 1). Examples of useful products in MLNG SATU are LNG, fuel gas and refrigerant whereas feed in MLNG SATU is in the form of natural gas (See Table 1 for the typical feeds and products in MLNG Satu). Higher PE means more useful products with higher energy were being generated for a given feed. PE is defined or calculated as follows:

\[
\text{Process Efficiency (PE)} = \frac{\text{Energy of Total Useful Product}}{\text{Energy of Total Feed}} \times 100\% \tag{1}
\]

| Feeds                           | Useful Products                        |
|---------------------------------|----------------------------------------|
| Natural Gas                     | Liquefied Natural Gas                  |
| Natural Gas Liquid              | Refrigerants                           |
| Steam (As Energy Input to Compressor Driver or as an heating medium) | Liquefied Petroleum Gas                |
| Electricity (As Energy Input to Pump Driver) | Fuel Gas                              |

This paper describes the framework of M-MAP and its associated methodologies for in-situ LNG process efficiency performance analysis. Combining with existing process control and optimization program, the framework offers elements for monitoring, diagnosis and simple prognosis that helps MLNG SATU in achieving higher LNG production and overall plant efficiency in day to day operation.

2. Methodology

MLNG SATU Molecule Allocation Program (M-MAP) consists of two phases with the objectives to determine the best combination of production target between LNG modules that able to achieve high plant efficiency of MLNG SATU and to determine efficiency gap in each module and process parameters that contribute to the gap.

The heart of M-MAP lies in its MS Excel embedded formula file. M-MAP MS Excel incorporates a detailed calculation of overall and individual’s mass and energy balance which will be used in calculating PE value in real-timeed basis within the desired time interval. Defining MLNG SATU’s process boundary is crucial when developing the mass and energy balances of the plant to prevent “over-counting” or “under-counting” of products and feeds that can lead to misleading of PE calculation as compared to actual plant efficiency of each module in MLNG SATU.

Once mass and energy balances are established, PE value can be calculated using the Equation 1. For data analysis purpose, MS Excel generates a correlation between PE and LNG production to find the equation’s slope. The slope is named as PE Slope.
PE Slope is crucial as an input to determine the best combination of production targets between modules towards higher overall plant efficiency in MLNG SATU. The slope of graph between these two parameters is the indicator to show the magnitude of the impact to PE as LNG production increases or decreases. Those modules with higher slope (i.e. PE/LNG production) should be given priority to increase production as the impact to PE improvement is larger than those with lower slope. When production has to be reduced, those modules with lower slope will have the priority in order to minimize the degree of reduction in overall PE. M-MAP MS Excel, based on the example given in Figure 1 will propose the sequence of priority as \( X \gg Y \gg Z \) when it comes to production increment and \( Z \gg Y \gg X \) when the production reduces.

![Figure 1. Typical correlation between PE and LNG production.](image)

M-MAP MS Excel file is then made available in a relay server that is located in between plant network and business network. By enabling information from the business network to be pulled by the plant network, it sanctions the communication between the M-MAP MS Excel file to Advanced Process Control (APC) Application. The option of having optimum operating parameters supported by an Advanced Process Control system is more and more applied and reported cost benefits are straightforward in terms of a better utilization of train capacity and smoother operation leading to a better efficiency [1]. This whole network combining M-MAP MS Excel and APC is named as M-MAP Real Time Optimizer (RTO). Once M-MAP RTO starts running, MS Excel file will automatically retrieve the plant data from existing plant data acquisition system using Visual Basic for Applications (VBA) scripting and calculate the real-timed PE value of each module at respective LNG production band.

In any application that has the functionality of giving inputs to APC for plant operation, the function for bad data filtration is vital to prevent APC from causing operation upsets. In M-MAP, in the case of bad plant data inputs due to instrumentation under maintenance, the MS Excel File is designed with an "error handler" function. This function will alert the unavailability of good plant data input to the user for rectification and will temporarily replace the real-timed plant data with the design values.

In addition, LNG production band is created. It will be used to group the PE values within the same production band for every time interval and calculate the average of PE values before developing the real-timed correlation with LNG production. This is one of the way to ensure that the PE values used in developing the correlation are truly representing the actual plant PE during the desired time interval.
Once the real-time PE slope values is generated upon the establishment of the correlation, it will be compared with the previously generated slope. To prevent too frequent changes in module priority during the implementation, the real-time PE slope values will only be transferred to Distributed Control System (DCS) when the difference in slope with the previous one is significant.

The PE slope values will be transferred to DCS via a script file located in the DCS server. M-MAP RTO will automate the module’s priority selection within the desired time interval by comparing each modules’ real timed PE slope values. The outcome from M-MAP RTO will be the input to “Landing Pressure Automation” and “Main Cryogenic Heat Exchanger Advanced Process Control” which determines which module production to be adjusted. Figure 2 shows an illustration of M-MAP RTO data transfer chronology.

While Phase 1 leverages on different PE between modules to determine the best combination of production to obtain higher overall efficiency of MLNG SATU, Phase 2 is established with the intent to reduce the gap of PE between modules. PE Gap Analysis Tool is introduced to identify reasons for the differences in PE and subsequently area for improvements to minimize the gap.

The tool is embedded inside M-MAP MS Excel File. The tool compares the daily energy performance of specific module with the best process efficiency performance that was achieved historically by any modules in MLNG SATU for the same LNG production range for the past one year, as illustrated in Figure 3 below. The benchmark values will be changed once the major gaps for a particular module has been rectified, normally during major turnaround or when the improvement has successfully brought the actual performance to or beyond the benchmark values.
In PE Gap Analysis Tool, the energy inputs (feed) and energy outputs (products) for particular module are listed separately between the input column and the output column. For energy inputs, the gap is defined when the actual energy is higher than the benchmark. Whereas, for energy outputs, PE Gap Analysis Tool introduces a new performance indicator which is “Low Heating Value (LHV) ratio” to identify the energy loss. The LHV ratio is defined as:

$$LHV \text{ Ratio} = \frac{Higher \text{ Energy Products}}{Leaner \text{ Energy Product}}$$ (2)

The ratio of high energy products over lean energy products is compared to identify the energy loss. From PE point of view, higher energy products for the same energy inputs is more desirable, hence the tool looks for gap when low LHV ratio is identified.

Once the gaps of particular energy inputs and outputs identified, the tool allows for the users to evaluate the process parameters that contribute to the gaps, such as pressures, temperatures, flows and composition. The benchmarked values for identified process parameters were also made available for the users to quickly identify the most plausible process parameters that contribute to the gap.

3. Results and Discussions

The implementation of M-MAP Phase 1 and Phase 2 has helped to increase overall process efficiency in MLNG SATU and at the same time minimise the PE gap among all three modules. Figure 4 shows improvement in overall process efficiency in MLNG SATU by 1.3% that is equivalent to 189 tonne/day feedgas saving, based on 6-month evaluation between pre and post implementation of M-MAP Phase 1.
As for Phase 2, several area of improvements to close the gaps in PE have been identified and actions have been planned for gap closure. Below are some of the summary of evaluation and findings obtained from the tool.

Higher steam consumption (energy input) for steam turbine in all Module X, Y, Z as compared to the benchmark by 20%, 10% and 5% respectively (see Figure 5). The tool identifies higher pressure at the surface condenser of steam turbine has led to higher steam flow to the turbine in order to compensate the loss in steam enthalpy for a given compressor power. Higher pressure at the surface condenser can be due to many reasons; among others are insufficient cooling medium or underperformance of ejector to remove noncondensibles medium from the system.

High steam consumption can be resolved by improving the cooling duty of the surface condenser and make good of ejector performance. It is projected that if the steam consumption can be reduced as per benchmark, an improvement of PE by 0.24%, energy saving equivalent to 33 tonne/day of natural gas upon resolution of this issue.

Module Y has higher steam consumption in heat exchanger by 15% as compared to benchmark (see Figure 6). This can be due to higher heating demand from process stream or inefficiency in heat transfer.
due to fouling. The evaluation found that this can be resolved by further optimizing steam flow consumption in Module Y with a more robust control strategy while waiting for a suitable window for maintenance. If the steam consumption in the heat exchanger of Module Y can be reduced at least as the benchmark values, it is projected an improvement of PE by 0.05% in average upon resolution of this issue, equivalent to 6.5 tonne/day of feedgas energy saving.

![Figure 6. Gap in steam consumption of heat exchanger against benchmark value.](image)

Module Y and Z have lower LHV Ratio by 75%-80% as compared to benchmark which indicates that the modules produce more lean energy products as compared to higher energy products. For example, producing fuel gas (methane dominant) as a product will lead to lower LHV ratio as compared to producing more LPG (propane dominant) for the same feed. In this case, Module Y and Z provide higher fuel gas export due to demand from other plants. From MLNG SATU PE point of view, exporting natural gas to other plant as fuel gas as opposed to producing LNG will reduce the process efficiency of these modules as fuel gas has lower energy content as compared to energy of LNG. Since April 2018, efforts has been done to control the treated natural gas supply from MLNG Satu modules by optimizing the fuel gas usage by other plants, hence, more natural gas from Module Y and Module X can be processed as LNG. The reduction of hot gas has improved the PE by 0.67 %, equivalent to 90 tonne/day of feedgas energy saving.

4. Conclusions

Molecule Allocation Program (M-MAP) was developed with the intention to have the best production and plant efficiency for MLNG SATU. The program has proven able to determine the best combination of production target among LNG modules that leads to high plant efficiency. Not only that, M-MAP is also capable to identify efficiency gap in each modules and the process parameters that contribute to the gap. This has led to several resolution initiatives created for MLNG SATU in 2017; approached either operationally or as part of maintenance activity. It is envisaged for similar LNG process efficiency performance monitoring and analysis to be embedded in other LNG Plants as well in order to maximize the realization of benefits to Petronas LNG Complex (PLC) as a whole.

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