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MANAGING CHALLENGES AT MLNG SATU DISTILLATION COLUMNS

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ABSTRACT

To realise the ultimate operating potential of distillation columns via maximising the yield throughput without compromising product quality at lower operating costs has always been an aspiration for Malaysia LNG Sdn Bhd (MLNG Satu). Existing Advanced Process Control (APC) has been helping the plant to deliver better process stability at the Fractionation Unit. Operating high-purity distillation columns in MLNG Satu imposes a challenge to APC control because of its non-linear and intensely interactive dynamics. In addition, frequent changes in feed compositions and feed flow must be dealt in a continuous basis, which failed to do so will results in a significant upset in the product compositions. The distillation process is also known to utilise a large amount of energy, which can significantly influence the overall plant profitability. Realising energy optimisation has a significant contribution towards overall operational costs in distillation columns' operation. Therefore this has become a prime target when performing APC revamp that recently took place at MLNG Satu (De-ethaniser, De-propaniser, De-butaniser column). This abstract describes the challenges and implementing control strategies to establish a disturbance feedforward model, minimise energy consumption and maintain optimum product impurity. Although distillation processes are inherently non-linear, a process control system based on linear input-output model can be acquired if operated over a sufficiently small region. Hence, a linear multivariable predictive control is developed, provides multi-objective control handling based on objective hierarchy. The applied control strategy has successfully improvised the dynamic control performance, resulting in a reduction in product quality variability, increment in product yield, and minimisation of the unit operating cost. It is expected to bring more value as the APC controller uptime increases over time. Intangibly, the competency of plant operators in dealing with advanced technology, i.e., APC, to optimise plant operation, has been enhanced from control to supervisory role, allowing for overall plant optimisation to be done in minute intervals.

Keywords: *Advanced Process Control (APC), Non-Linear, Distillation Columns*

INTRODUCTION

MLNG Satu consists of three identical modules, namely Module 1, 2, and 3. Each module has its respective Fractionation Unit incorporating four distillation columns, De-methaniser, De-ethaniser, De- Propaniser & De-butaniser, which are arranged in series together with the associated equipment (i.e., condensers, reboilers, pumps, etc.) to perform fractional distillation of the feed. In general, the feed to the distillation columns is a mixture of methane, ethane, propane, butane fraction, which comes from two sources, 1) MLNG Satu bottom scrubber with leaner feed compositions and 2) MLNG Dua bottom stabiliser, which contains heavier feed compositions and enters at the top tray of De-mechanised column.

The methane fraction is reinjected into the Natural Gas stream. At the same time, ethane and propane are stored in the refrigerant tank to be used as a"cooling element" in both Mixed Component Refrigerant (MCR) and propane circuits. Propane is an essential component in driving the liquefaction process in LNG plants, specifically in PETRONAS LNG Complex.

Being the main compound to provide pre-cooling of Natural Gas (NG) and Mixed Component Refrigerant (MR), a slight deterioration of the propane refrigerant composition could significantly reduce LNG production. As propane refrigerant is contaminated, the cooling duty reduces significantly, causing difficulty to achieve desired LNG temperature resulting in LNG production reduction. Hence, De-propaniser is designed as a high purity column with 99.8% product quality to ensure the propane specification.

Problem Statement

Operating high-purity distillation columns in MLNG Satu imposes a challenge to APC control because of its non-linear and intensely interactive dynamics. Non-linearity is a known issue when operating a distillation column, and it usually involves a trade-off between energy usage and purity of product quality. The previous focus of the APC controller was on achieving target product quality and minimise product giveaway, with less attention given in maximising the energy efficiency.

In addition, frequent changes in feed compositions and flow, which majorly consist of MLNG Satu lean gases and MLNG Dua rich gases, must be dealt with continuously. Failure to do so will result in a significant upset in the product quality at all four distillation columns. Existing APC only considers the combined feed flow as its disturbance variable instead of the respective feed flow from these two sources. In addition, the absence of a feed gas analyser at each of the columns has cause difficulty for the APC controller to define the actual feed compositions, thus impacting the dynamic stability of the column and incorrect adjustment by the APC controller.

Scope & Objective

To cater to these issues, the operating region at MLNG Satu De-methaniser, De-ethaniser, De- Propaniser & De-butaniser columns is re-defined, focusing on determining the linear distinct dynamic behavior at each of the columns while meeting the process objective and realising the economic opportunities. It is crucial to outline the linear operating region as the existing APC controller can only function well in a linear and small non-linear region using its multivariable predictive control. The applied APC control strategy provides multi-objective control handling based on objective hierarchy to improve the dynamic control performance, resulting in a reduction in product quality variability and minimises the unit operating cost.

METHODOLOGY

Advanced process control (APC) is a control strategy that utilises process stability to initiate the optimisation process. The control strategy will initially strive to stabilise critical controlled variables (CVs), which are perceived to affect the optimisation process, within or at a certain constraint, either set-range or setpoint. To achieve the CVs within or at constraints, the APC will control manipulated variables or handles (MVs), mainly controller setpoint or control valves' opening, which can affect the process response of the CVs. Once good stability and controllability are achieved within the critical constraints, the APC will initiate an optimisation process of selected Economic Variable (EV), utilising some or all of the MVs used to stabilise the process.

In 2019, APC revamped carried out in MLNG Satu distillation columns with some enhancement done to the controller objectives as below,

1. Maximisation of heavies at the respective overhead product of De-ethaniser and De-butaniser column within its allowable design limit by increasing the overhead temperature. This allows the column to be operated in a non-pure region, thus sanctioning the linear input-output APC model to function effectively. In addition, maximisation of heavies composition also helps to increase the product yield of Ethane and Butane.
2. Similarly, for a high purity De-propaniser column, the operating region is shifted to allow slight propane slippage to its bottom product, thus ensuring stringent propane refrigerant specification at the overhead product is met. Operating the bottom product in non-pure mode has increased the robustness of the APC controller in the linear operating region, thus prevent unnecessary upset to the column operation.
3. On top of that, both feed gas sources from MLNG Satu and MLNG Dua have been incorporated as disturbance variables to improve the model

prediction accuracy, further considering frequent changes in feed gas flow rate and composition.

4. Lastly, energy optimisation is put as a priority by operating the reflux flow at its optimum value, considering the ratio between the reflux rate and feed rate, while at the same time ensuring the product specification is taken care of. Operating reflux flow at its optimum limit has eventually reduced the reboiler duty requirement and minimises the column operation cost.

RESULT AND DISCUSSION

Commissioning of APC revamp in MLNG Satu distillation columns has enabled process parameters to be operated closer to its specification limits and continuously pushed against its constraints while achieving better consistency of overhead/bottom product quality control. Reduction of product variability enables the process to move to an optimum setpoint with higher product yield while allowing some minimum impurities to ensure linear process dynamic is established across the whole operating region. As illustrated in Figure 1, lower process variability of De-ethaniser overhead temperature is achieved, shown by reduction in its standard deviation by 53.12% post-APC revamp. This has helped significantly improve the maximisation of propane impurities in ethane products and pushed it closer to the allowable specifications limit of 11 mol %, as shown in Figure 2. Higher impurity composition has also resulted in an increase in ethane product yield to the refrigerant tank.

On the contrary, for a high purity column like De-propaniser column, reduction of product variability at the bottom temperature is pivotal before allowing some minimum amount of propane slippage to the De-butaniser column. Previously, maintaining the optimum target for propane impurities in overhead De- butanizer is strenuous and dramatically limits the opportunities in recovering more propane products. Post APC revamp, a notable improvement of the bottom temperature is achieved, with a reduction in its variability by 71.35%, hence allowing minimisation of product impurities give away to downstream column as illustrated in Figure 3.

The preceding discussion involved a reflux operation that plays a vital role in controlling energy consumption. As shown in Figure 4, operating at higher reflux flow leads to an increase in the reboiler duty or steam flow. Thus higher energy cost is required. In addition, too high reflux flow will also influence the overall separation, causing the column to be operated in too pure a condition. The non-linear region will exist and impact the APC controller's dynamic stability.

A new parameter of Reflux/Feed (R/F) is incorporated as one of the main controlled variables in the new APC to govern the optimum reflux flow. Post-

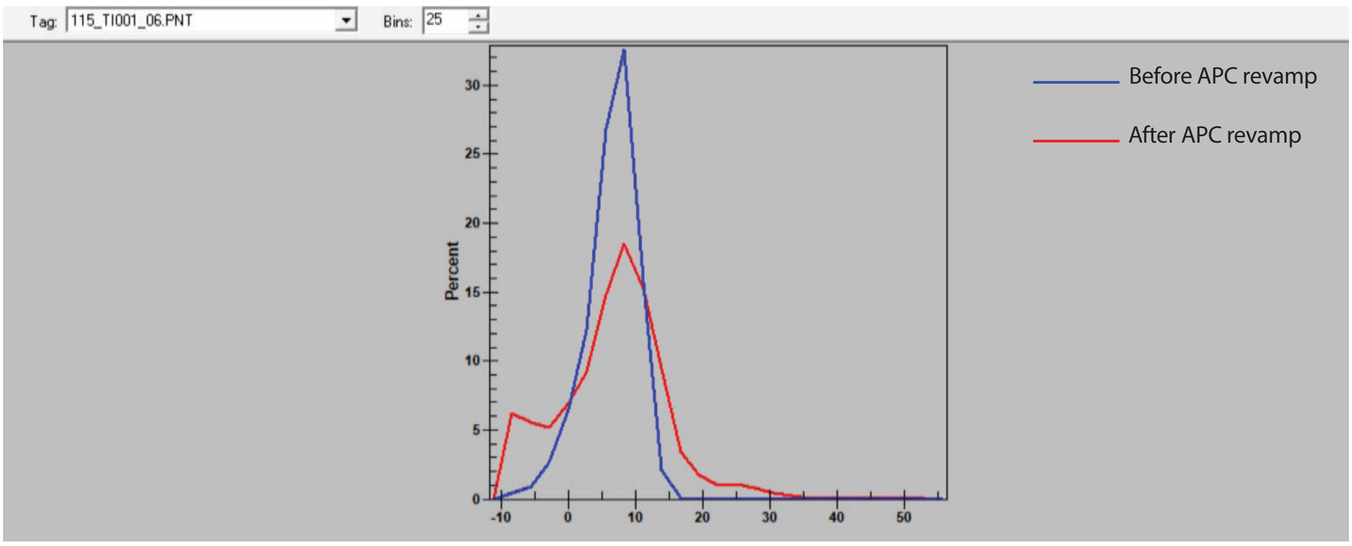

Figure 1 Histogram of overhead temperature at De-ethaniser column

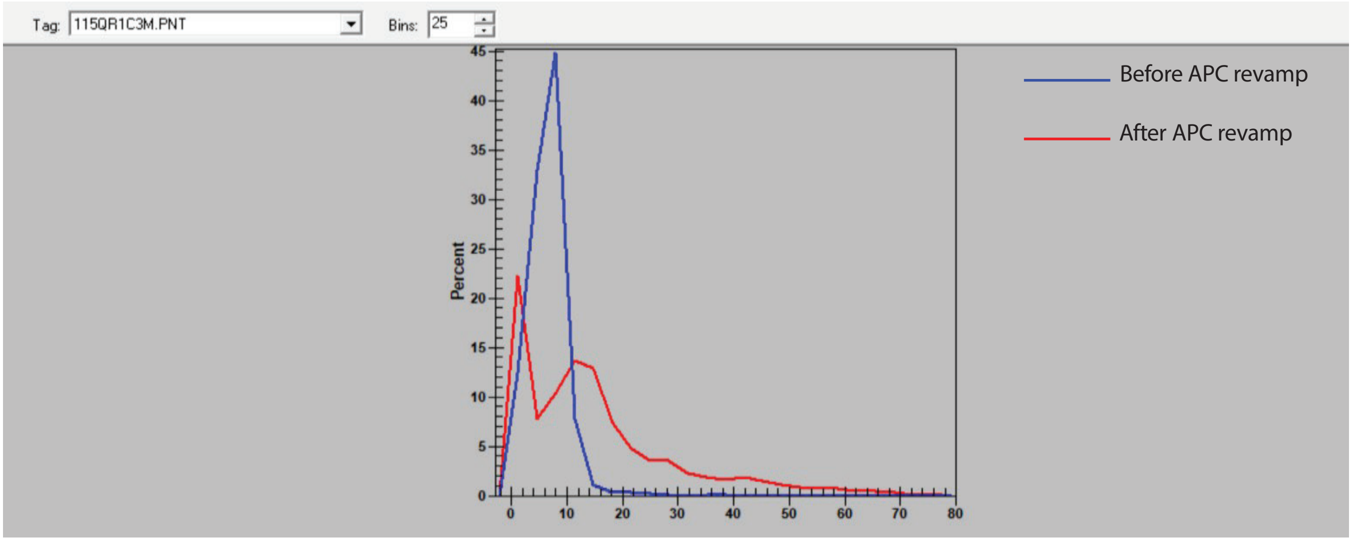

Figure 2 Histogram of propane impurities in ethane product at overhead De-ethaniser column

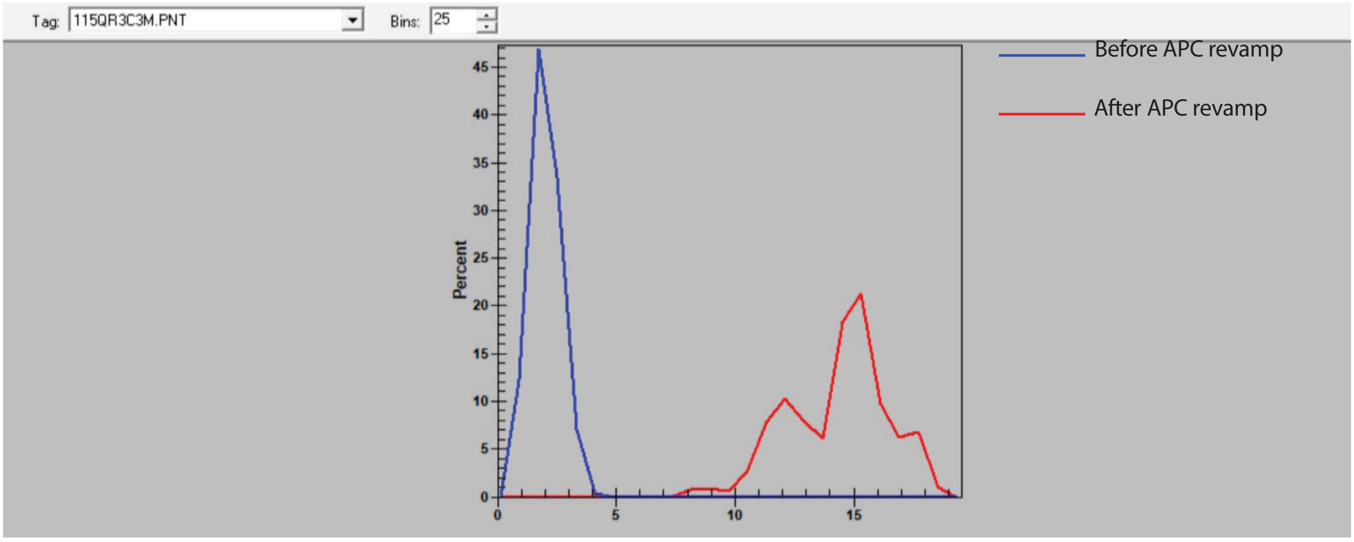

Figure 3 Histogram of propane impurities in overhead De-butaniser column

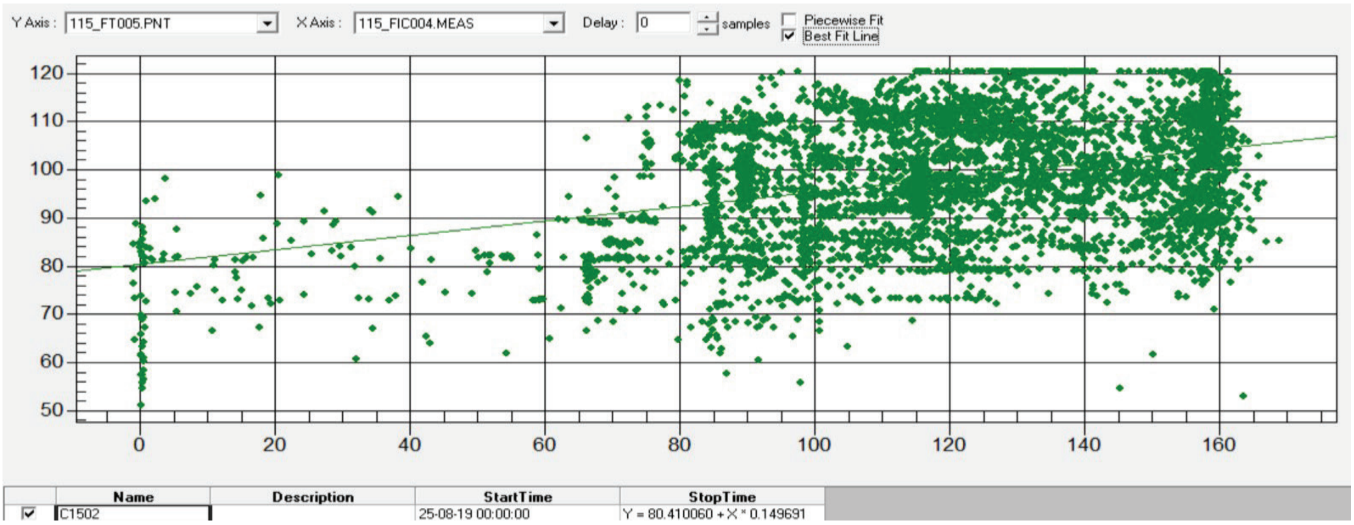

Figure 4 X-Y plot of steam flow vs reflux flow

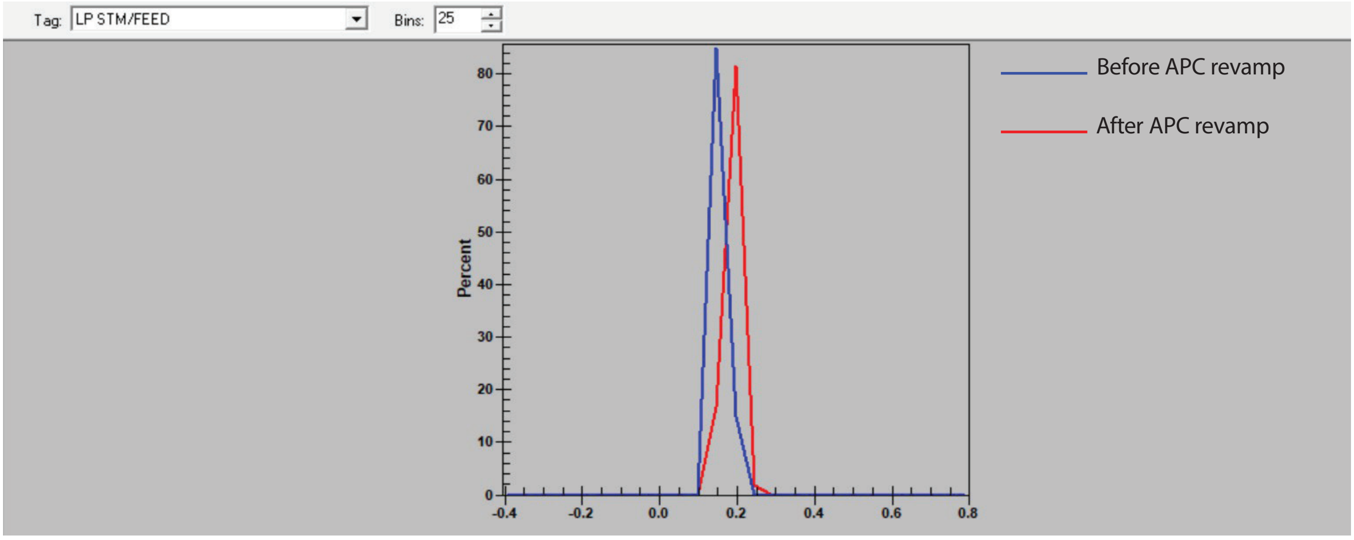

Figure 5 Histogram of Steam flow/Feed flow in De-ethanizer column

implementation of this new controlled variable, the reflux flow is adjusted accordingly subject to its feed flow while ensuring the R/F ratio is well controlled within its ranges. The reduction in both variability and the average reflux flow has resulted in lower energy duty, shown by a reduction in the average Steam flow/ Feed flow to De-ethaniser column by 15% from 0.19 to 0.15 and improvement in its variability by 35.8%, as shown in Figure 5.

CONCLUSION

In essence, a significant reduction in the process variability in a distillation column is necessary to allow the process parameters to be operated closer to their specification limits. This will then results in a reduction in the product giveaway and an increase in product yield. For a high purity distillation column, non-linear behaviour is expected, which will influence the ability to achieve the ultimate target of the separation unit. However, if operated over a sufficiently small region, a process control system based on a linear input-output model can be acquired. The applied control strategy has successfully improvised the dynamic control performance, resulting in a reduction in product quality variability, increment in product yield, and minimisation of the unit operating cost.

REFERENCES

S. Putri, "Process Control Narrative MLNG Satu Fractionation Unit", Bintulu, 2015.

Arunachalam, "Operating Technical Reading Material of MLNG Satu Fractionation Unit", P1-U1500-2010, 2011.

"Functional Design Specification (FDS) for MLNG Satu SMOC U-1500"

F. Izyan, "Post Implementation Review for MLNG Satu Advanced Process Control at Fractionation Unit", Bintulu, 2019.