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Optimizing Diesel Production Using Advanced Process Control and Dynamic Simulation

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Abstract: This paper describes the economical and operational benefits achieved with the use of advanced process control techniques and dynamic simulation applied to a Naphtha Splitter Column. The project consists in optimizing the Diesel blending system of Henrique Lage Refinery (REVAP) located in the state of São Paulo, Brazil. The control strategy was designed to maximize production rate, respecting the operational constraints. The results include an increase in the Naphtha flow stream to the Diesel blending system and improvement of the operational stability, leading to valuable economic gains. The project is also a step forward in the use of Dynamic simulation for modelling and identification, where the simulation models have shown to be representative for the inferential variables integration, adding value to the final result.

Keywords: Advanced Process Control; Optimization, Dynamic Simulation, Naphtha Splitter, Distillation.

1. INTRODUCTION

The use of advanced process control (APC) strategies in the industry has consistently increased in the past few decades and became common practice among those willing to extract all the economic potential of the process, [Delaney, 2012]. Although maximizing their products yields seems to be the primary objective, it is clear that these projects also improve the process safety and operational continuity, among other potential benefits, [Nello, 2011]. Part of the APC success is credited to the evolution of hardware robustness, computational efficiency and software development presented in commercial packages that make possible the implementation of more sophisticated and complex model-based control algorithms. Despite all its potential, it is mandatory to pay special attention to the operational staff's training, [King, 2012] and some other important issues, such as model representability in order to avoid the APC project failure, [Lodolo et al., 2012].

Dynamic simulation is a powerful instrument with modelling capabilities that have been recently adopted by control engineering practitioners. It has given engineers the opportunity to validate new control strategies, obtain dynamic models for inferential variables, supply valuable information for hazop analysis, economical studies report and give assistance during operators training. Virtual plants make possible to study the plant behavior over different scenarios [Al-Dossary et al., 2008], including those undesirable ones where the real plant should not go, [Blevins et al., 2003], [Mansy et al., 2002]. This represents a large improvement on the system's overall reliability, [Luyben, 2012].

This paper presents an application that shows the advantages of combining APC strategies and Dynamic simulation for optimizing a Diesel blending system in a large Brazilian refinery. The APC was designed for maximizing Naphtha addition in the blending system as it handles the Diesel product's flash point. The result is an economic gain associated to the conversion of Naphtha in Diesel, which represents a higher value product, [Kelly and Mann, 2003], [Campos et al., 2013] . The process is detailed in section 2. Section 3 discusses the optimization issues considered for the unit and the benefits of using dynamic simulation for modelling and identification. Section 4 presents some results regarding economical achievements and operational improvements reached by the implemented APC. A conclusion is given to summarize the questions raised throughout the paper and add some perspectives for further improvements.

2. PROCESS DESCRIPTION

The REVAP's Diesel blending system consists of three intermediate products streams: The Diesel streams from the Coker Gasoil Hydrotreating Unit (HDT-GOK) and the Diesel Hydrotreating Unit (HDT-D) and the Heavy Naphtha stream from the Naphtha Splitter Column. These three streams are blended to compose the refinery's Diesel product that is sent to storage. This product must meet the national petroleum agency specifications for certification and commercialization. Otherwise, it is sent for reprocessing, which represents large economic losses for the refinery. The Naphtha addition lowers the Diesel's flash point and its flow is limited in order to avoid off-specification. The Diesel blending system is illustrated in Fig. 1

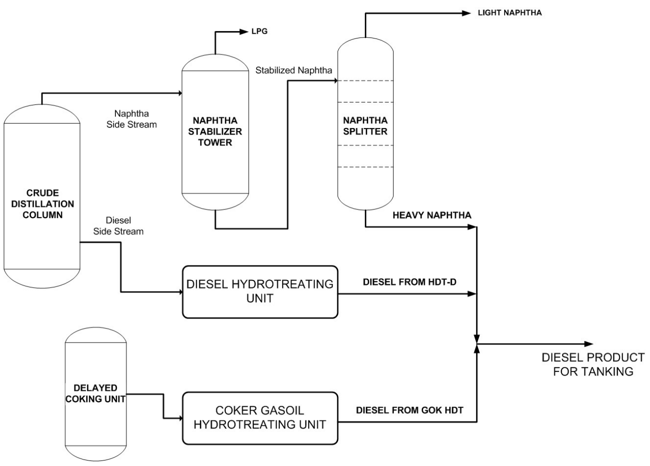

Fig. 1. Diesel blending system.

The Naphtha splitter Column is illustrated in Fig. 2. The inlet stream is composed by the Stabilized Naphtha that comes from the Stabilizer Column of the Crude Distillation Unit. The Splitter's sensitive plate temperature is controlled by the heat exchange between medium pressure steam and the column's side reflux. The top reflux is composed by the Light Naphtha from the top separator vessel and the excess is exported as Petrochemical Naphtha. The column's bottom flow is composed by the Heavy Naphtha, which is added to the Diesel blending system. Since Diesel has a higher economic value when compared to Naphtha and the column's top stream adds no economic value, the economic yields are proportional to the Heavy Naphtha stream that is sent to the Diesel.

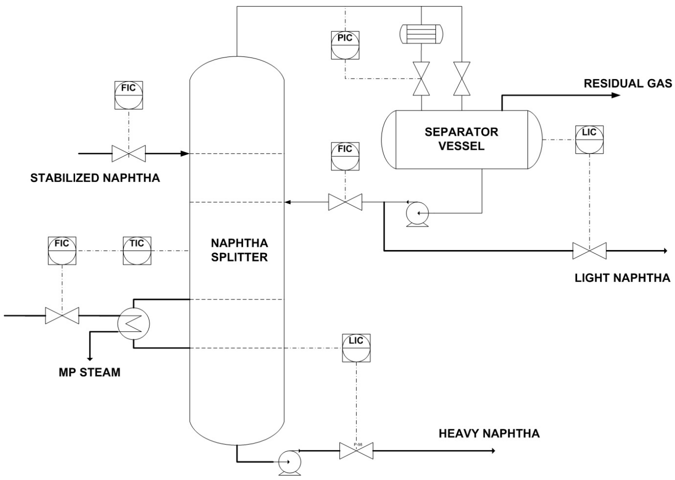

Fig. 2. Naphtha Splitter.

3. OPTIMIZATION

The optimization project of the Naphtha Splitter Column consists in maximizing the processed feed and the Heavy Naphtha flow, which means increasing the refinery's Diesel production. The optimizer is designed to compensate the effects of changes in the feed composition to keep the controlled variables inside the operational range. Also, the lack of on-line and off-line analysers leads to the need of estimating the Heavy Naphtha's flash point. The optimization's objectives were reached through the use of advanced process control and dynamic simulation.

3.1 Advanced Process Control

The designed APC is a two-layer optimizer with the stationary layer running a Quadratic Programming (QP) algorithm used for steady-state optimization and constraints handling, generating the targets for the manipulated and controlled variables (MVs and CVs) of the dynamic layer, where the Cutler's *Dynamic Matrix Control* (DMC) algorithm, [Cutler and Ramaker, 1980] is used for targets tracking and disturbance rejection. The two-layer optimization strategy is illustrated in Figure 3. The QP algorithm, [Garcia and Morshedi, 1986] solves the cost function given by equation (1), [Zanin et al., 2007]:

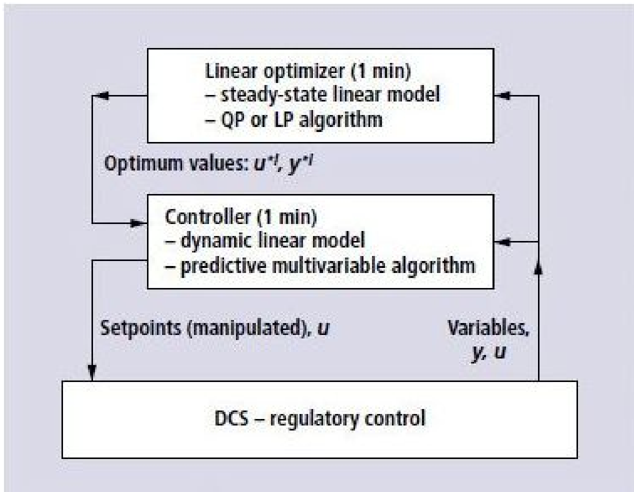

Fig. 3. APC with Two-layer strategy. [Rotava and Zanin, 2005]

$$\min_{\Delta U, SCV} -W_1 \Delta U + \|W_2 \Delta U\|_2^2 + \|W_3 SCV\|_2^2 \tag{1}$$

subject to:

$$\Delta U = U_S - u_{at}$$
$$U_S^{inf} \leq U_S \leq U_S^{sup}$$
$$Y_S^{inf} \leq Y_S + SCV \leq Y_S^{sup}$$

where $W_1 = diag[\frac{\partial f_{eco}}{\partial u_1}, \frac{\partial f_{eco}}{\partial u_2}, \ldots, \frac{\partial f_{eco}}{\partial u_n}]$ is the diagonal matrix of the economic coefficients of the manipulated variables (MVs), W_2 is the diagonal matrix of the suppression factors of the MVs and W_3 is the diagonal matrix of weights for the *slack* variables (SCV) used for constraints softening. These three matrices are, in fact, the tuning parameters of the optimization layer. The steady-state optimization uses a linear economic function, thus the W_1 coefficients are constants and they are related to the economic yield achieved with the increment / decrement of the associated MV. U_S is the vector of MVs steady-state targets, u_{at} is the previous control action, U_S^{sup} and