LAGRANGEAN DECOMPOSITION APPLIED TO MULTIPERIOD PLANNING OF PETROLEUM REFINERIES UNDER UNCERTAINTY

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Abstract— **This work presents a stochastic multiperiod model for representing a petroleum refinery. Uncertainty is taken into account in parameters such as demands, product sale prices and crude oil prices. In the present work, uncertainty is considered as a set of discrete scenarios, each representing a possible shifting of market expectations. Every environment is weighted through an expected probability of occurrence. Previous work revealed that the computational effort of uncertain multiperiod refinery production planning models grows exponentially with the number of time periods and scenarios. Therefore, in order to reduce the computational effort over uncertain long-planning horizons, special techniques must be employed. The proposal is to apply Lagrangean Decomposition, which exploits the block-diagonal structure of the problem, to reduce solution time by decomposing the model on a temporal basis. Solution of the proposed algorithm showed a significant reduction in computational effort with respect to the full-scale outer approximation solver.**

Keywords— **Lagrangean decomposition, uncertainty, petroleum refinery, planning, MINLP.**

I. INTRODUCTION

Commercial tools that can support the decision making process of production planning of refineries are currently based on linear models that rely on constant yields. This limitation motivated the developed of more accurate representations. One of the first contributions to consider nonlinearity in the production planning is that of Pinto and Moro (2000). According to their proposed framework, every unit is represented as an entity and the complete refinery topology is defined by connecting unit streams. Nonlinearity arises mainly from blending equations and physical properties. Later, Neiro and Pinto (2005) extended the model by accounting for multiple time periods and uncertainty expressed in terms of discrete scenarios.

In order to tackle the large computational effort that results from the size of planning problems, tailored solutions strategies were developed. Ponnambalam et al. (1992) developed an approach that combines the simplex method for linear programming with an interior point method for solving a multiperiod planning model in the oil refinery industry. Neiro and Pinto (2006) developed decomposition methods that are derived from the cross -decomposition theory that prevents the use of master problems. The proposed strategies rely on methods such as Lagrangean decomposition and Lagrangean/surrogate relaxation.

The objective of this paper is to develop efficient solution techniques for multiperiod planning models under uncertainty. The refinery planning model of Neiro and Pinto (2005) with discrete scenarios and corresponding probabilities assigned to the possible market environments is used. The resulting model generates large-scale MINLP problems that are then solved with Lagrangean-based decomposition methods.

II. PROBLEM STATEMENT

The problem to be considered concerns a real-world production planning of the REVAP refinery from Petrobras, located in São José dos Campos (SP, Brazil). A broader discussion on refinery models for planning operations can be found in Pinto *et al.* (2000) and Neiro and Pinto (2005). Generally, it is assumed that in each unit intermediate inlet streams are always mixed and intermediate streams that leave any unit may be sent to several destinations. Therefore, there may be mixing (splitting) before (after) each of the units. The refinery may acquire crude oil from different suppliers that are able to provide petroleum types with different properties and purchase prices. The refinery produces several products that present varied demand profiles and selling prices along a planning horizon that is divided into t discrete time periods of equal duration, $t \in \mathbf{T}$. In addition, uncertainty for petroleum purchase prices, product selling prices as well as product demands are represented through discrete scenarios, $c \in \mathbf{C}$. Each scenario is weighted according to its occurrence probability as detailed in the following section.

III. UNCERTAINTY SCENARIO REPRESENTATION

The main goal of a model that considers uncertainty is to provide a forecast to the planner of how the refinery should perform under several possible scenarios that result from different values of the stochastic parameters. Moreover, it should be noted that solutions do not change depending on the distribution of the probabilities assumed for each scenario. Table 1 shows solutions of an illustrative example in terms of the feedstock selec-