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# Application of global optimization strategies to refinery hydrogen network

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ABSTRACT

In this paper, a new method is presented in optimization of hydrogen network. The mixed integer non-linear programming (MINLP) and non-linear programming (NLP) problems have been solved with two methods, simultaneously. The linearization technique for non-linear programming models which proposed by McCormick (1976) and also a new method proposed by Faria and Bagajewicz (2011) have been used to solve these problems. Application of this new method is presented in global optimization of MINLP/NLP, and hydrogen network problem.



## Introduction

Petroleum refineries include many processes involving hydrogen production or consumption. Optimization of hydrogen network is a necessary issue to achieve the optimal allocation of hydrogen resources and satisfy the demands of refinery processes. The optimization of hydrogen network problems has used some methods. Amongst these methods are Pinch Analysis based conceptual approaches [1–5] and Mathematical Programming [6–18].

Alves developed a framework of sinks and sources for the hydrogen network based on pinch technology similar to heat exchanger network [2]. The Pinch Analysis provides a good view for a designer. Unlike the Pinch models, adding new equipment, the optimal equipment emplacements and the optimal cost of network are considered in the mathematical

*Abbreviations:* LP, linear programming; NLP, nonlinear programming; MINLP, mixed integer nonlinear programming; MEN, mass exchanger network; PSA, pressure swing adsorption; LP OFF GAS, low pressure off-gases; HP OFF GAS, high pressure off-gases; RI, hydrogen recovery ratio to PSAI; RII, hydrogen recovery ratio to PSAII; ypI, product purity to PSAI; ypII, product purity to PSAII; yrI, residual purity to PASI; yrII, residual purity to PASII; yfI, feed purity to PSAI; yfII, feed purity to PSAII; LB, lower bound model; UB, upper bound model; ALB, auxiliary linear model.

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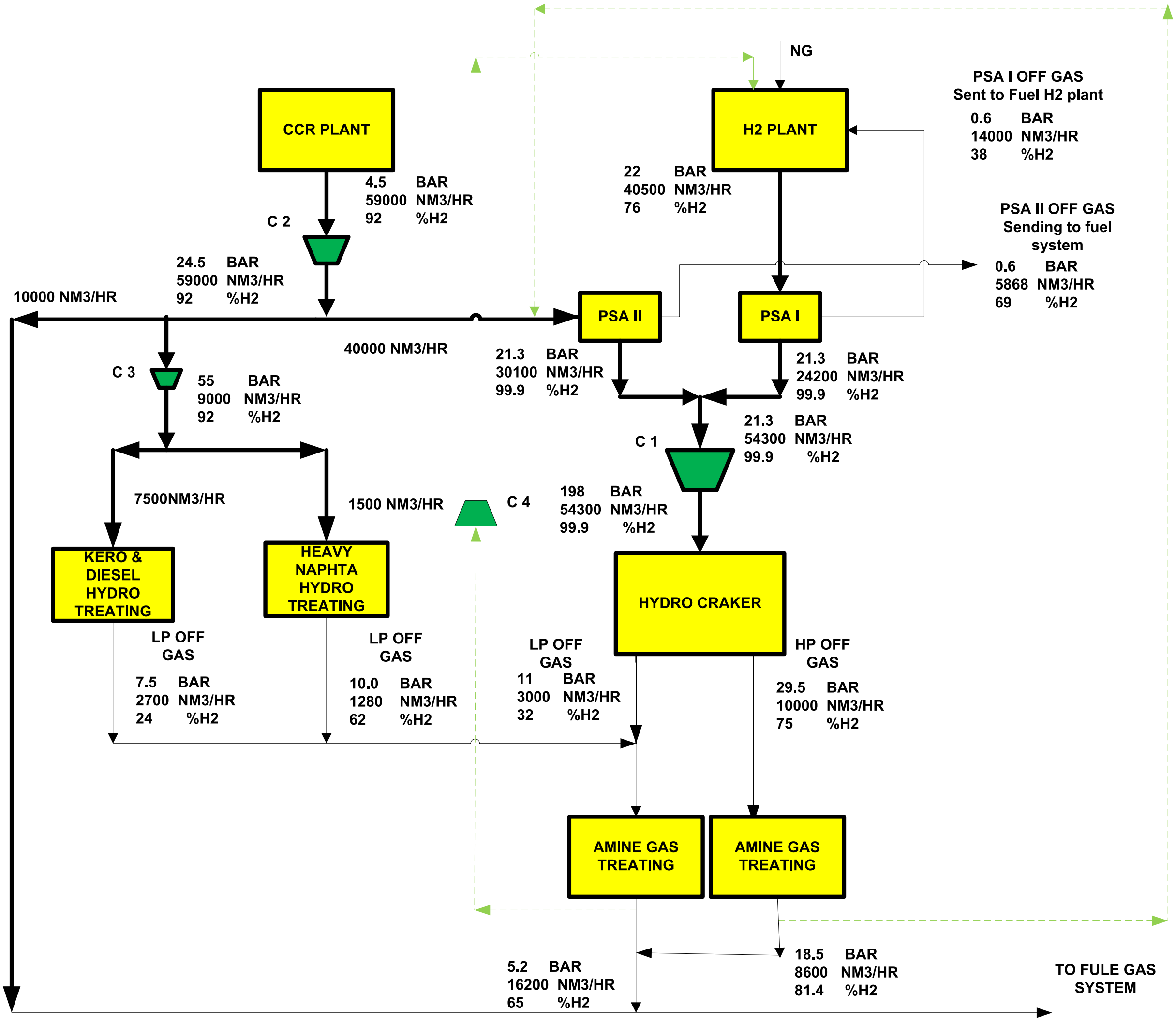


**Fig. 1 – The current network hydrogen.**

models pressure constraints. Furthermore, the Pinch models can only handle linear problems, while extensions to nonlinear problems have not been developed. The hydrogen network structures are considered in the forms of NLP, MINLP and MILP models [16]. On the other hand, the mathematical formulation of bigger networks or operating conditions and numerous constraints may lead to create local values in optimizing process. As a result, the global optimization value cannot be obtained for such networks.

In this study, a multistage optimization algorithm is applied for solving the global optimization of hydrogen network problem which was a combination of the bound contraction procedure and the linearization technique. This paper is organized as follows:

At the first, the mathematical formulation of the hydrogen network problem and the contraction procedure are presented. After that, the upper and lower bounding process, which is used in the approach, and also the linearization technique and the equation bounds converge to global optimum are considered. Finally, the results, which were obtained by solving hydrogen network problem for an Iranian refinery, are presented.

## Methods

### *Mathematical formulation of the hydrogen network problem*

The hydrogen can be distributed to three major components [10], including hydrogen distribution network, purifiers, and compressors. The hydrogen distribution network includes the whole sources, sinks, and connections between them [10]. Fig. 1 indicates the hydrogen network for this case study.

*Hydrogen sources*

Hydrogen sources are streams containing hydrogen, which can be sent to the consumers [3]. The total amount of gas which is sent to the hydrogen network must be equal to that one which is available from the source:

$$F_{\mathrm{source},i} = \sum_j F_{i,j} \tag{1}$$

*Hydrogen sinks*

Hydrotreaters and hydrocrackers are the major consumers of hydrogen in a refinery plant. The amount of gas, entering the