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Research Paper

Investigating the Production Management and Optimization of Hydrogen Gas

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1. ABSTRACT

Heavy crude oil cracking units (hydrocracker) and crude oil desulfurization (hydrotreater) are the two most important hydrogen-consuming units in the refinery. Affected parameters such as hydrogen consuming units and environmental rules increase the necessity of optimization the hydrogen network in the refinery. In this article, we intend to obtain the optimal hydrogen network structure in Abadan Refinery using the superstructure method. The superstructure method includes a mathematical model that is able to provide the hydrogen necessity by consumers and design the optimal hydrogen network with the lowest cost. The results of optimization show the hydrogen from RPS CRU and COLD-SEP CRU streams, which were sent to the fuel system before optimization can be recovered and reused in the network. RPS CRU and COLD-SEP CRU flow rates of 5000 and 3600 (kg/h), respectively, with relatively high purity of hydrogen, can be sent to the PSA purifier for the recovery. In addition, regarding to the recovery there is no necessity to utilize the hydrogen production unit (U-57) and it will be taken out of service, and as a result, the purchase cost of the hydrogen production unit will be removed from the network.

Keywords: Refinery, Optimization, Hydrogen Network, Hydrogen Recovery, Pressure Swing Adsorption (PSA)

2. INTRODUCTION

A set of different factors, including the limitation of fossil resources, negative environmental effects, the use of hydrocarbon resources, the increase in the price of fossil fuels, political conflicts and its effects on the provision of sustainable energy are among the reasons that many politicians and it has forced the experts on energy and environment issues to move towards creating a new structure based on the security of energy supply, environmental protection, and improving the efficiency of the energy system. Based on this, hydrogen is one of the best option to play the role of energy carrier in the new energy production system. Simultaneously with the expansion of the use of heavy crude oil in refineries, the amount of hydrogen use has also increased. Heavy crude oil has a lower drilling cost due to its proximity to the surface of the earth, and as a result, its use as a low-cost raw material has been welcomed. But this type of oil has a lot of sulfur and it should be treated with hydrogen (hydrotreating) to reduce its acidity. On the other hand, stricter rules are applied every day on the amount of harmful substances in the produced oil as well as the pollution coming out of the refinery. In these laws, the amount of sulfur in light oil is continuously reduced, and as a result, hydrotreating operations and hydrogen consumption increase. In addition, heavy crude oil is transformed into light valuable products in refineries by hydrocracking so that it can be marketed [1-2]. All these factors increase the need for hydrogen management and hydrogen network optimization. In fact, hydrogen management reduces the consumption of hydrogen utilities, optimizes the hydrogen network and reduces additional costs in the refinery. In fact, the hydrogen network, with its high importance in

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the refinery industry, requires a more conceptual and appropriate view of it and a new approach in hydrogen management and optimization of the hydrogen network [3-4].
The purpose of this article is to optimize the hydrogen network for the first time in Abadan Oil Refinery using the hydrogen recovery method. In this research, first, the entire structure of the hydrogen network, including consumer units, hydrogen producers, and compressors, is modeled using the superstructure method. Then, the most valid mathematical model presented for hydrogen purification units (PSA) is added to the structure of the superstructure. In the end, optimization has been done using the modeling done with the aim of reducing the production of fresh hydrogen in the network.

3. HYDROGEN NETWORK

In general, each hydrogen network in refineries consists of three main parts [5]:
1- Hydrogen sources
2- Hydrogen consumers
3- Hydrogen Recovery (Purifiers and Compressors)
In fact, the connection between these three parts forms the hydrogen network in such a way that for hydrogen management in the refinery, the most optimal connection between the network elements and the most effective structure in the network must be created. In the following, the relationships and mathematical equations governing the different parts of the hydrogen network are examined.

a. HYDROGEN SOURCES

All streams that can send hydrogen to consumers are called hydrogen sources. Therefore, the amount sent to the sinks (consumers) should be equal to the amount of output from the sources [6].

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

b. HYDROGEN CONSUMERS

The most important consumers of hydrogen include hydrotreaters and hydrocrackers. In order to maintain the performance of all consumers (sinks), the amount and degree of purity of the incoming hydrogen in these units should be kept constant [6].

$$F_{sink,j} = \sum_{i} F_{i,j} \tag{2}$$

$$F_{sink,j}\, y_{sink,j} = \sum_{j} F_{i,j}\, y_i \tag{3}$$

c. HYDROGEN RECOVERY (Purifiers)

The most widely used hydrogen purification units are PSA and membrane. These units can receive hydrogen from several streams with different purity and send it to several consumers with high purity. Generally, a purifying unit is considered as one sink (refiner input) and two sources (high purity product output and Residual) in the hydrogen network system. This is well illustrated in Figure 1.

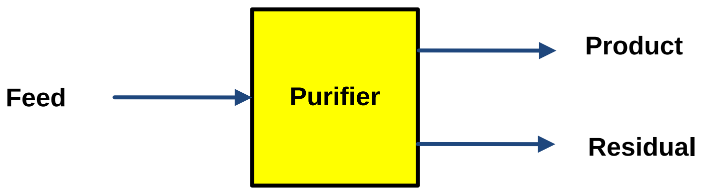

Figure 1. Hydrogen purification unit, with one sink and two sources

4. RESULTS AND DISCUSSION

Figure 2 shows the optimal structure of the hydrogen network of Abadan Refinery.

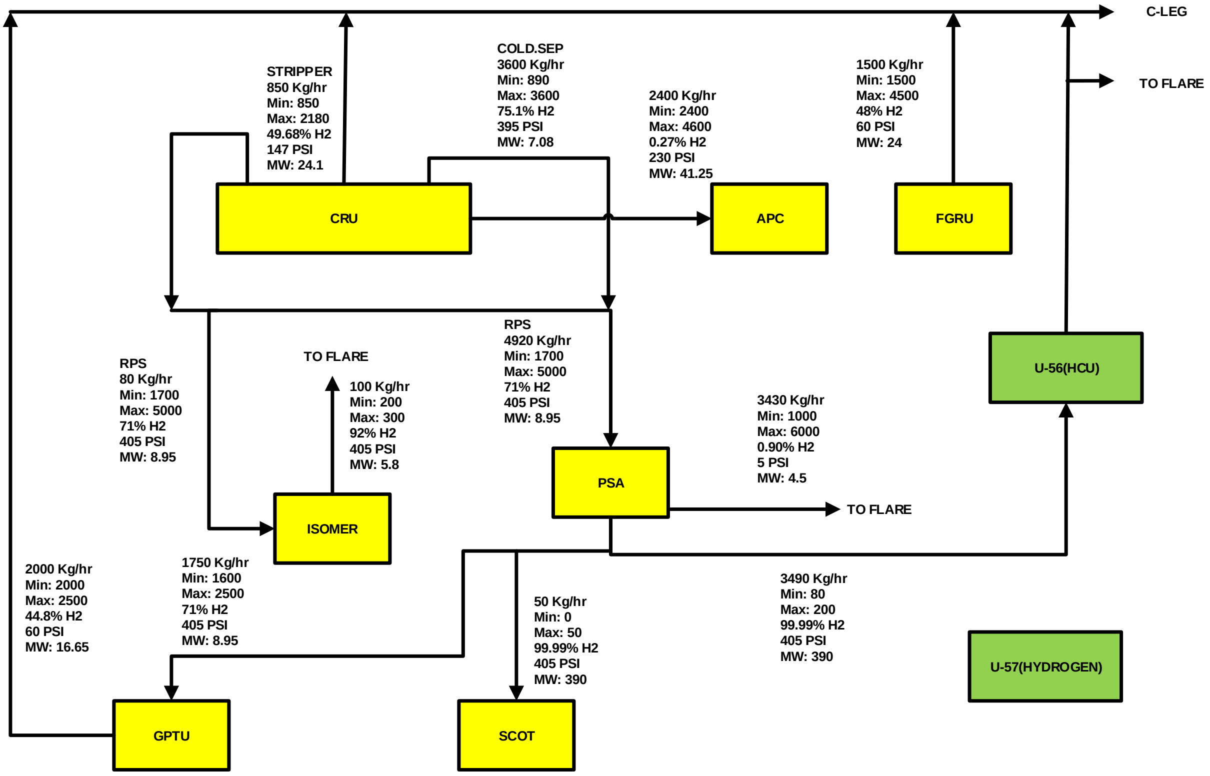

Figure 2. Optimal structure of hydrogen network of Abadan Refinery

In this article, the optimal structure of the hydrogen network in Abadan refinery was proposed using the superstructure method. The superstructure method includes a mathematical model that is able to provide the hydrogen needed by consumers and also design the optimal hydrogen network with the lowest cost. The objective function used in the optimized network is to reduce the amount of hydrogen produced from the hydrogen production unit. The results after optimization show the reuse of hydrogen sent to fuel. Also, the COLD-SEP CRU stream with a relatively high purity of hydrogen is sent to the PSA purifier for recovery. The results show that due to the supply of hydrogen to consumers through the recovery of waste hydrogen, the hydrogen production unit (U-57) can be in shutdown mode and will be removed from the system. In the optimal network structure, the flow of RPS CRU unit with a relatively high purity of hydrogen, which previously sent a large amount of flow to the fuel system, flows to PSA and Isomer after optimization. Also, the PSA unit is working at its maximum capacity.

5. REFERENCES

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