Resource efficiency indicators usefulness for decision-making process of operators: refinery hydrogen network case study

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NOTE: The following is a summarised version of the published conference paper of Galán et al (2017).

Abstract

Process industries worldwide are constantly challenged by competitiveness, being forced to produce goods that meet specifications with the least possible costs. Therefore, optimisation of consumed resources has become of utmost importance in the process industry. However, it is not crystal clear how to better approach resources minimisation without affecting production outputs. One of the most recently supported strategies is working out resource efficiency indicators (REIs), summarising key process information. REIs should aid operators in the decision-making process, while fulfilling production and safety requirements at all times. Moreover, data has to be available and easy to interpret almost on real-time in order for operators to actually take action promptly.

Based on a case study of a refinery hydrogen network, comprising 4 producers and 14 consumers, REIs are defined and monitored. Basically, applying data from real-time reconciliation and optimisation tools, convenient REIs have been determined and analysed. REIs are aimed at bringing added value to operators in daily complex decisions on processes, facilitating production goals achievements even under contingencies. In brief, the more hydrocarbons processed with the least hydrogen production, the better overall efficiency. Thus, REIs should gather and condense key information about process status, and operators should aim for optimum hydrogen distribution across the network while maximising overall production.

Starting from validated estimators, that represent online (sampling time = 2 h) reconciliation and optimal distribution of the network (De Prada et al., 2017), REIs are defined and monitored. There are two important considerations about REIs. First, their scope has to be selected properly in order to be informative: if the scope is very narrow, they may indicate benefit for a plant that can be negative when considering the impact on a wider scale, like a network. Second, REIs should be as independent as possible of external disturbances and reflect the actual impact of current operation on the aspect under consideration. In this way, changes of the REIs are good indications to operators about the way the process is being conducted. One type of REIs particularly important from that point of view are those that relate one desired feature to the best value this feature can have (e.g.: optimum) in the current conditions (feed, weather, etc.). For example, ratios of actual and optimum global variables such as: H2 and HC ($R_{H2}$ and $R_{HC}$, respectively), which are used in this work (see Table 1).
Regarding the case study, three types of REIs are defined: unit specific (UREIs), global (GREIs) and combined (CREIs). The first is scoped at plant level, whereas the second and third are network concerned. UREIs and GREIs are: convenient ratios of either actual data (reconciled) or optimal values (see Table 1, Eq. 1-2). CREIs are calculated as functions of GREIs ($R_{H2}$, $R_{HC}$) that have independent contributions to network overall efficiency. In particular, two REIs of plant HD3 and four global REIs are analysed. An important point to consider when defining REIs, is the fact that sometimes there are conflictive aims, so that improvements in a certain feature have to be balanced with possible decrements in others. In order to facilitate the interpretation of the REIs, a combined REI can be defined, reflecting the evolution and priorities of the elementary ones. In this paper we make use of such CREIs and the rest are UREIs.

Table 1 - REIs considered, descriptions, units and equation reference. * Not applicable, CREIs are a function of dimensionless GREIs.

| REI  | Units          | Description                                           | Equation |
|------|----------------|-------------------------------------------------------|----------|
| $R_{U1}$ | Nm$^3$/m$^3$  | Chemical consumed $H_2$ per HC load                   | Eq.(1)   |
| $R_{U2}$ | Nm$^3$/Nm$^3$ | Chemical consumed $H_2$ per Make-up $H_2$             | Eq.(1)   |
| $R_{u2}$ | Nm$^3$/Nm$^3$ | Total $H_2$ produced (optimal) over total $H_2$ produced (actual) | Eq.(1)   |
| $R_{HC}$ | m$^3$/m$^3$  | Total HC load (actual) over total HC load (optimal)   | Eq.(1)   |
| $R_{FG}$ | Nm$^3$/Nm$^3$ | CBP $H_2$ to FG (optimal) over CBP $H_2$ to FG (actual) | Eq.(1)   |
| $R_{C1}$ | NA*          | CREI accounting $R_{H2}$ and $R_{HC}$ effect on network efficiency. | Eq.(2)   |

$R_Z = \frac{X}{Y}$  \hspace{1cm} (1)

Where:

$X, Y$ are either: reconciled or optimal values of the respective stream (e.g.: make-up $H_2$, HC load) or sum of stream (e.g.: total $H_2$, total HC).

$Z$, REI identification index.

$R_{C1} = (1 - \alpha) \times f(R_{H2}) + \alpha \times R_{HC}$  \hspace{1cm} (2)

$f(R_{H2}) = \frac{- (R_{H2})^2 + 2 \times R_{H2} + 1}{2}$  \hspace{1cm} (3)

Where:

$\alpha$, is a weighting factor from 0 to 1 ($\alpha = 0.65$).

Data gathered and processed over 8 days for REIs shown in Table 1 are presented and discussed in the published version of this paper (Galan et al, 2017).

Conclusions

UREIs, GREIs and CREIs, are analysed and discussed with some detail. UREIs showed limited utility for determining operational efficiency, possibly due to the effect of loads quality. GREIs presented some degree of independence from feed qualities. Additionally, $R_{H2}$ and $R_{HC}$ proved certain degree of usefulness for the support of operators in the decision-making process,
however they are deemed less efficient than CREIs in this aspect. CREIs demonstrated efficient monitoring of the network, considering the two-dimensional problem; however, further research should be encouraged to tackle some open issues, such as: how to account “unfeasible” combinations of $R_{\text{H}_2}$, $R_{\text{HC}_2}$, and analysing other function forms of CREIs.

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References

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