Multistage operations flexible design: towards a more conscious energy consumption in separation processes

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Abstract

The transition of process industry towards renewable energy sources and sustainable raw materials is one of the key steps towards the decarbonization of chemical processes [1]. However, beside the nature of the energy source, an important contribution can be obtained by improving the way it is consumed. In this perspective, heat duties play a major role on the overall emissions of a plant [2].
Since the early design stages, the engineer is asked to find the best economic compromise between capital and operating costs. This procedure mainly refers to nominal operating conditions and rarely accounts for emissions. In particular, in multistage operations, the optimal number of stages is one of the variables that are optimized by means of the remaining degrees of freedom. However, when perturbations occur, since the equipment already exists, the process has to compensate with a higher energy consumption with respect to the optimal value and, thus, with higher emissions.
That is why, in this article, the OPEX definition is reconsidered accounting for the deviation likelihood and an optimal number of stages according to a more flexible design choice is presented. The research analyzes the results for two separation processes, namely a multiple-effect evaporator [3] and a distillation column [4]. In both cases, the most relevant emission item is represented by the heating duty and the related energy consumption as indicated in literature [5].
The study shows that higher investments during the design phase in terms of number of equilibrium stages corresponds not only to a more flexible operations when perturbations are likely to occur but also to a lower energy consumption and, thus, lower GWP and more sustainable operations.
The approach is then worth to be extended to entire plants section in order to validate the conclusions also for whole chemical processes.

Keywords: optimal design, multistage operations, uncertainty, energy consumption, sustainability.

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