Assessing the Controllability of Heat Exchanger Networks.

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Extended Abstract

Improving energy efficiency is probably the most generic issue for the process industry today, and process integration is a common tool to successfully achieve this. However, an increased level of process integration, usually implemented by re-circulation and other physical feedback structures, can increase the complexity of the dynamics drastically. This, in turn, implies increased control difficulties and may make implementation unfeasible.

There are methods to assess the energy efficiency of existing heat exchanger networks (HENs) and identify modifications of the current design to improve the heat recovery. However, they are generally based on steady state models and give no information about the dynamic performance. As choices concerning stream splits, heat exchanger size and placement may significantly impact the controllability of a HEN, it is of principal importance to not only optimize with respect to cost but also with respect to controllability when designing HENs. As the methods for design or retrofit of HENs may identify several alternative designs with similar economic performance, controllability can be the deciding factor for which solution to implement. Moreover, in some cases failure to take controllability into account may lead to that the proposed design, while perhaps optimal from a steady state economic stand point, may be impossible to control properly. To create a design of a HEN that includes controllability concerns there need to be strong metrics to assess the controllability of a design.

When assessing the controllability of a HEN, the relative gain array (RGA) is generally used [1]. The RGA serves two purposes, it recommends an input-output pairing for decoupled control of the HEN, while also giving a measure of the HEN's controllability. However the standard RGA is based on the static gain of the system, so it does not contain information about the dynamics of the system.

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Even though the RGA can be expanded to take into account systems dynamics, and this has been proposed for heat exchanger networks [2]. However this is still not used when optimizing HENs for optimal controllability, see e.g. [3, 1]. Hence, it is justified to compare the RGA of HENs with alternatives that take into account the dynamics of the system, such as the dynamic RGA [4] and Hankel interaction index [5] and others. By doing these comparisons, cases, for which the RGA may not give a reliable indication of the controllability of a HEN may be found.

To properly model the dynamics of HENs, the models need to be expanded to include information about the pipes connecting the heat exchangers as briefly discussed in [6]. As the pipes' properties have little impact on the steady state of the network and hence, also the RGA, they are often ignored when assessing a HEN's controllability. However, the pipes may certainly have an impact on the dynamics of the system and should then be included in the controllability assessment. Moreover the temperature of some streams may be controlled by other means than heat exchangers, for example by furnaces. The dynamics of these components, as well as for example non-isothermal mixing of streams, need to be included in the models as well.

As stated previously, the RGA gives recommendations for an input-output pairing for decoupled control of the HEN. This decoupled control is then often implemented using PI or PID controllers. However, as HENs tend to be systems with relatively slow dynamics and potentially long delays, this indicates good opportunities to improve the control performance by utilizing feed-forward when controlling the network. Changes or disturbances that occur at the beginning of a stream takes time to propagate to the end of the stream and consequently it should be possible to preemptively compensate for them downstream.

Dynamic aspects of controllability of heat exchanger networks, like the ones described above, and their implications for how heat exchanger networks should - and should not - be designed, are studied in an ongoing doctoral project. The project is a cooperation between Preem, CIT Industrial Energy and two research groups at Chalmers; Automatic Control and Industrial Energy Systems and Technology. The methods will be developed by Chalmers and CIT-IE and applied on selected process areas at Preemraff Lysekil. The selected applications are chosen based of their high energy efficiency potential, high level of heat integration and complex effects on the control of the existing plant. The project is funded by Preem and the PiiA program.

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