Designing a Total Site for an Entire Lifetime under Fluctuating Utility Prices

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Summary

This paper describes a synthesis of Total Site in order to obtain additional energy savings by process-to-process heat integration. Enhanced Heat Integration and economically viable designs can be obtained by establishing an appropriate trade-off between the operating cost and the investment. The aim of this work was to improve the modeling of the Total Site by including proper pressure levels selection for intermediate utilities, preheating of intermediate utilities because of incomplete condensate recovery, pipeline layout design, and optimal pipe design with optimal pressure/temperature drops and optimal insulation thickness and heat losses during transportation along the pipes. Additionally, future utility prices are considered when synthesizing the Total Site as they are expected to influence the trade-off between investment and operating cost. A stochastic multi-period mixed-integer nonlinear programming model for the optimal synthesis of Total Site over its entire lifetime has been developed by including all the above-mentioned design aspects.

Main Findings

The heat integration within a Total Site shows a significant potential for energy recovery. However, an optimal design has a significant influence on the economic viability. It is even more crucial to obtain a proper design for a heat exchanger network within a Total Site, as the heat is transferred twice: (i) from hot streams to intermediate utilities, and (ii) from intermediate utilities to cold streams. Both heat transfers require heat exchangers and also a pipeline for connecting the source and sink sides in which additional pressure/temperature drops and heat losses occur. Therefore, the trade-off between investment and operating cost is even sharper. In this work a stochastic multi-period MINLP model was developed for the synthesis of a Total Site and the optimization of its heat recovery in order to consider also future utility prices. The results of the case study indicated that it is necessary to account for:

• All interactions between source and sink HENs and the pipeline, which gives rise to the use of the simultaneous approach. The ENPV obtained in the case study by the simultaneous approach was increased by 64.5% and a 21.6% reduction in external hot utility consumption was achieved, when compared to the sequential approach.
• Pipeline investment, as the fraction of the pipeline investment within the total investment cannot be neglected; in the case study presented it was up to 34.2% of the total investment.
• Optimization of pressure levels, as it can significantly improve ENPV when compared to the cases with fixed pressure levels. In the case study ENPV was increased by 32.9% and external hot utility reduced by 29.5%.
• Future prices of energy, as they can have additional impact on the trade-off between investment and operating cost. In the case study it lead to 17.9% increase of ENPV and to the 31.9% reduction of external hot utility, when compared to the optimization at current utility prices.
• Heat losses, as in the presented case study it represented even 44.8% of heat gained on the source side when no preheating was considered, whilst in the case of incomplete recovery of the

condensate it was 15.8 times higher than those through the pipeline.

• Pressure drops simultaneously with the evaluation of pipe diameters. In the case study they were less significant; however, as they reached almost 4 bars in certain pipelines, they already reduced the heat content of steam and caused temperature drops of utility supply at the sink side, which influenced somewhat the trade-off between investment and external utility consumption. The results of the case study clearly indicate that accounting for all heat losses and pressure/temperature drops in the Total Site can have a significant impact on the economic performance.

The proposed approach improves the modeling of Total Sites in many respects in order to obtain more realistic solutions and can therefore help significantly the efficiencies of decision making about Total Site design. In the future better optimization of pipeline layout based on a more detailed superstructure needs to be developed as it might have a significant impact on a Total Site performance. In addition, research is under way related to the reduction of the model size. This can be achieved by reducing the multi-period model to a single-period one. The reduction is valid when the entire investment is constructed within the present period as better solutions are obtained when the investment is spent at the beginning of lifetime.