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Research paper

Process modification of Total Site Heat Integration profile for capital cost reduction

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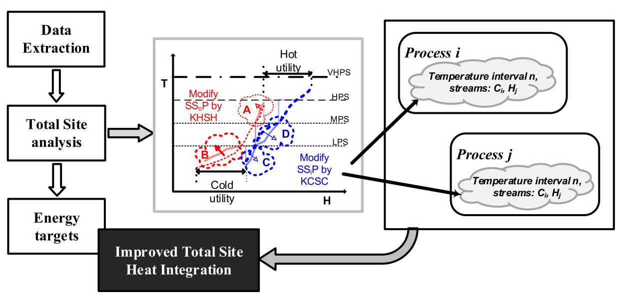
HIGHLIGHTS

- Total Site Profile (TSP) directed approach to process modifications.
- Increased temperature driving force to reduce capital costs.
- Manipulate TSP shape using keep hot stream hot and keep cold stream cold principles.
- Target process modifications at selected TSP segments to improve Heat Integration.
- New heuristics to prioritise the changes in TSP segments and process streams.

GRAPHICAL ABSTRACT



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ABSTRACT

The Total Site Profile (TSP) can be a powerful tool to evaluate the potential for further Heat Integration improvement for a Total Site (TS). A systematic Total Site Heat Integration (TSHI) methodology to target decreasing the capital cost of heat transfer units at Total Sites has been developed. The methodology includes a set heuristics that have been developed to identify and prioritise the strategic process changes to apply, as a result of changes in the TSP shape. The TSP and expanded Total Site Problem Table Algorithm (TS-PTA) can provide useful insights for the plant designers to identify "where", in terms of which temperature interval, and which streams within the entire TS to focus the process modification efforts. The keep hot stream hot (KHSH) and keep cold stream cold (KCSC) principles can be applied to favourably change the TSP shape to provide a larger temperature driving force to further reduce the HTA and capital costs. In one of the case study, the application of KHSH and KCSC on TSP increases the temperature driving force between the medium pressure steam utility and process resulting in a reduction of 3,827 m^2 heat transfer area (HTA) and a saving of 10% in heat exchangers cost. The proposed changes to the selected streams should be assessed from feasibility, practicality and economic perspectives. The selected and potentially acceptable process modification options can be conveniently merged with potential retrofit project (e.g. to increase plant capacity) considered for the Total Site.

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1. Introduction

Most processing industries rely on fossil fuels as the main source of energy. Pressure from the depletion of fuel resources and climate change due to emission CO_2 from burning of fossil fuel has made improving energy efficiency imperative. Heat Integration (HI), a concept that has come about in the 1970's has contributed significantly in the development of solutions for improving energy efficiency [1]. HI by the use of Pinch Analysis was first introduced by Linnhoff and Flower [2] for single process. Dhole and Linnhoff [3] later extended the Pinch based HI application to Total Site (TS). A TS consists of two or more individual processing plants linked by a common utilities system. Heat Integration of the processing plants within the TS are most often effected indirectly by the use of intermediary fluids such as steam. Total Site Heat Integration (TSHI) offers much opportunities for energy saving as seen in the several industrial case studies reported. A study on a large Swedish industrial cluster consisting of five chemical companies showed that a potential 50% saving in energy bills can be achieved with moderate changes to the process utilities system if collaboration can be negotiated among the companies [4]. Another study on a large Japanese large steel plant showed that even when individual processing units are of high efficiency, implementation of TSHI can still provide saving when the heat quantity and distribution is analysed systematically [5]. In an industrial milk powder production plant case study Walmsley et al. [6] demonstrated that by combining two heat exchanger networks and with some small changes to a few selected process stream temperatures, significant saving and energy and cost can be achieved.

The TSHI methodology is made of a set of graphical tools. The overall heat surplus (Source) and deficit (Sink) of the processes in a TS are represented by the Total Site Profile (TSP). The potential utility generation from the source and heating requirement of the sink are depicted by the Site Utility Composite Curves (SUCC) which are then used to set the targets for site heating and cooling utilities requirements [7].

The TSP and SUCC of TS is comparable to the Composite Curve (CC) of a single process. Linnhoff and Vredeveld [8] developed well-known strategies for process modifications such as plus-minus principles, keep hot stream hot (KHSH) and keep cold stream cold (KCSC), appropriate placement of utilities, etc. by exploiting the shape of CC to improve heat recovery in single process. These modification strategies developed for single process can be extended to TS to identify scope for changes in process or utility systems that will bring about TSHI improvement. Hackl et al. [5] showed that the gap between the TSP and SUCC can be used as an indicator to target changes in utility system to increase heat recovery between site source and sink. By using hot water instead of low pressure steam, the gap between the hot utility CC and the site sink is reduced thereby improve TSHI. Nemet et al. [9] used the plus and minus principles on TSP to evaluate the merits of integrating new process to an existing TS. Only new process that result in improved overall heat recovery are recommended for integration to the TS. Chew et al. [10] demonstrated how the plus-minus principles can be applied on TSP to target processes modifications that are beneficial to TSHI. The plus-minus principles are discretely applied to the three regions of TSP: above, at and below the sink and source overlap area. The identified changes on TSP is then linked to the specific changes at the individual processes. Liew et al. [11] applied the plus and minus principles on the SUCC in a petrochemical complex retrofit case study. The plus and minus principles are used along with Site Pinch to select the utilities to reduce and/or upgrade in order to satisfy the retrofit objectives of reducing site energy consumption. Boldyryev et al. [12] proposed a methodology to estimate the minimum heat transfer area (HTA) in TSHI by optimising the intermediate utility temperature for each enthalpy interval (which corresponds to the temperature interval on the TSP plot). While this method provides a target for the minimum HTA, it may be impractical to implement when the number of intermediate utilities required is large.

The energy targets from TSHI depend on both the TSP, i.e. the operating conditions of the individual processes, and the utilities system on the TS. Changes in both process and utilities operating conditions can alter the energy targets. Previous research has shown that there is much potential to improve TSHI by exploiting the potential process changes that are feasible. The impact of utility system changes on TSHI can be deduced straightforwardly. However, the impact of process changes on TSHI, favourably or otherwise, cannot be easily inferred. In addition, most process modifications are often evaluated within a particular process rather than in TS context. Some Pinch strategies for process modifications such as exploitation of soft data, appropriate use of minimum temperature of approach (ΔT_{min}) and suitable use of insulation can be applied directly on TS, others such as Plus-Minus principles needed to be adapted for TS [10]. The TSP can be a powerful tool to evaluate the potential for further heat recovery improvement for a TS. This study proposed a directed approach to target process modifications that can favourably change the TSP shapes that would result in a reduction in heat transfer area and consequently the cost of heat exchangers at TSHI.

2. TSP directed approach to process modifications for TS

Process designer/engineer often looks at process individually when scouting for process modifications opportunities to improve HI on a TS. The potential process modifications identified are evaluated to generate a list of feasible options. This exercise is then repeated for all the other processes one by one. Little consideration is given to the impact of process changes on TSHI. After all the feasible options have been identified, they are evaluated, one by one, for their impacts on TS. This process is repetitive, exhaustive and time consuming as shown in Fig. 1(a). On the other hand, the TSP can be strategically used to pinpoint temperature range and candidate streams where changes can bring about favourable results to TSHI. By bringing the individual process analysis within the TS context, the designer/engineer is able to avoid performing rigorous evaluation of all possible processes. This makes the task less iterative and less time consuming as depicted in Fig. 1(b). Process efforts can then be focused based on the targeted stream/process within the TS.

The Pinch based TS analysis uses the selected streams' data to produce the Grand Composite Curve (GCC) for each process. The process GCC shows the heat deficit and surplus above and below the Pinch. The heat surplus from each process are combined to produce the Site Source Profile (SS_oP) and the heat deficits combined to generate the Site Sink Profile (SS_iP) in the TSP plot [13]. The TSP present a succinct summary of heat deficit and surplus at various temperature levels in a TS. From the TSP, potential process areas to target process modifications to improve TSHI can be identified.

In this study, the application of KHSH and KCSC principles is selected to demonstrate the approach. The principles of KHSH and KCSC are as simple as the acronyms, i.e. maximise the hot stream supply and/or target temperatures and minimise the cold stream supply and/or cold supply and target temperatures. The application KHSH and KCSC principles on single process to reduce energy targets and/or capital cost saving by increasing the temperature driving forces is explained e.g. by Kemp [14] and illustrated by Klemeš et al. [15].