CHEMICAL ENGINEERING TRANSACTIONS

VOL. 39, 2014

A publication of
AIDIC
The Italian Association
of Chemical Engineering
www.aidic.it/cet

Guest Editors: Petar Sabev Varbanov, Jiří Jaromír Klemeš, Peng Yen Liew, Jun Yow Yong
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ISBN 978-88-95608-30-3; **ISSN** 2283-9216 DOI: 10.3303/CET1439304

Data Acquisition and Analysis of Total Sites under Varying Operational Conditions

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The procedure of data acquisition under uncertain operating conditions is presented when retrofitting existing plants and Total Sites (TSs). Heat Integration (HI) and TS Heat Integration (TSHI) are performed within larger-scale industrial plant. Several studies exist regarding performing HI and TSHI under fixed conditions, both for grassroots designs (minimum energy requirement designs) and for retrofits. They have been some studies published only, which have completely address how to perform internal plant HI and TSHI when the fluctuation of operational conditions are considered at the larger scales, such as within petrochemical plants. The data acquisition for HI and TSHI under varying operational conditions still needs more attention. Those two issues are tackled by the presented work.

1. Introduction

Expanding economic and environmental issues and global competition have forced industrial companies to improve the performances of their processes and especially TSs and Locally Integrated Energy Sectors (Perry et al., 2008). There are several opportunities for savings: reducing the energy consumption and increasing the energy production by selling the excess electricity, heat and/or cold at the peak times. Savings can be achieved by retrofit modifications. A previous work has been presented by Liew et al. (2014a). A site with several production plants experiences frequently unsteady supplies both in quantities and qualities of feedstock, and uncertainties on the demand side due to market prices and demands. Consequently flow rates, temperatures, and other parameters mostly vary (Shah et al., 2011). The work dealing with variable heat supply and demand published recently Liew et al. (2014b) and for shifting for hybrid power systems based on Power Pinch Analysis by Wan Alwi et al. (2014). This contribution presents an example of process plants HI and TSHI in order to reduce energy consumption, produce intermediate utilities, and to improve economic and environmental performances of a process and/or TS. The first required step for retrofits is related to data acquisition of the plant and TS level. Data acquisition should consider various uncertain operating conditions. Those data should be used as an input of software tool for Process Integration and retrofit analysis, such as SPRINT (SPRINT, 2012), STAR (STAR, 2012) and recently EFENIS Site (CPI Manchester, 2014) and TransGen (Čuček et al., 2014). For the overview of available software tools for this purpose till 2011, see contribution by Lam et al. (2011). The scope for improvements should be obtained. The retrofit options should be identified and selected as the next step. The suggested modifications should improve the economic and environmental performance in general, by considering fluctuations. The procedure for the data acquisition and TS Analysis under varying operational conditions is presented by conducting a study of existing petrochemical TS. For this purpose, two different

Please cite this article as: Čuček L., Yong J.Y., Mantelli V., Vocciante M., Varbanov P.S., Klemeš J.J., Karlopoulos E., Kravanja Z., 2014, Data acquisition and analysis of total sites under varying operational conditions, Chemical Engineering Transactions, 39, 1819-1824 DOI:10.3303/CET1439304

tools developed under EFENIS Project (2013) are used: Efenis Site software (2014) and TransGen framework (Čuček et al., 2014). Case study of an industrial application with significant number of heat transfer units is used to demonstrate the procedure. This procedure is suited for industrial applications with significant fluctuations in operation and/or when number of heat exchangers is large.

2. Data acquisition under varying operational conditions

The required steps for data acquisition under uncertain operating conditions for retrofitting industrial TSs are presented in this section. Figure 1 presents the steps for data acquisition and TSHI for varying operating conditions. The procedure starts with detailed flowsheet of all the processes which are optional to be retrofitted, continues with elaboration of the data for each case and creation of the Problem Table (.Klemeš et al., 2010). The data extraction can be provided by on line information system within the plant, by adjusting measured values and estimating unmeasured streams (Vocciante et al., 2014). The data for analysis covering various cases are an input for a software tool. Modifications are valid for all the investigated cases. Mostly an iterative process for the final selection of heat exchanger network (HEN) modifications is needed.

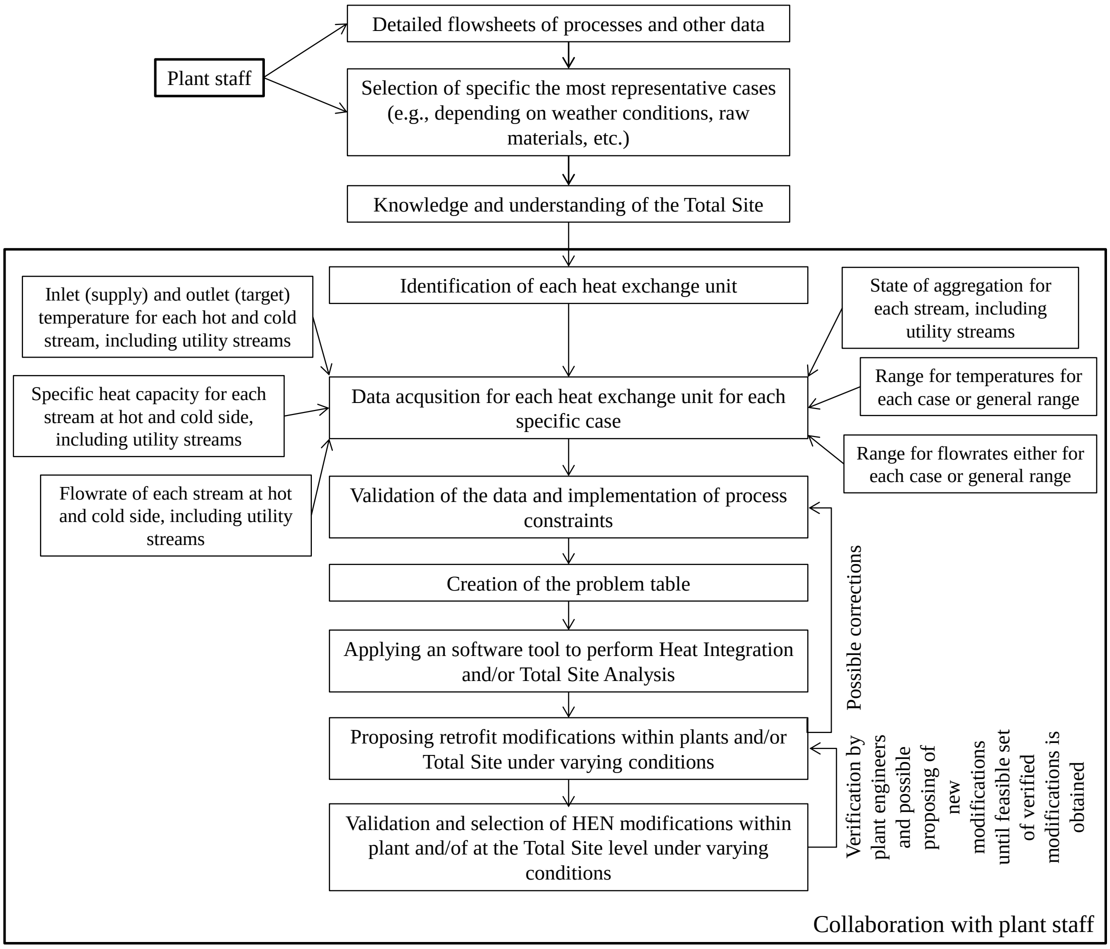

Figure 1: Suggested procedure for data acquisition and TSHI under varying operational conditions

The suggested approach starts with the existing network and seeks to identify the most significant changes required in the network structure either from energy reduction viewpoint or from economic viewpoint. The procedure regarding data acquisition and Internal HI and TSHI is illustrated by conducting an industrial demonstration case study of the refinery refining diesel oil, low sulphur fuel oils, and bitumen.

3. Industrial case study of HI and TSHI under varying operational conditions

Operations of several production plants fluctuate due to different supplies and qualities of feedstocks, changing market prices and demands (Shah and Ierapetritou, 2010), weather conditions etc. HI and TSHI

are performed on an existing industrial case study. First HI within each unit (four units 1 – 4) and THSI for an entire investigated industrial site is performed under fixed operational conditions (condition 1) using Efenis Site software. Analysis under varying conditions is performed using software TransGen. For the reasons of simplification and because total integration could only be performed within two units (units 1 and 2), only those two units are analysed under varying operational conditions.
The data for process units are obtained from the company, and consider the fluctuation of temperatures, flows and specific heats. Operation under four different conditions is assumed. There are two main intentions to be dealt with in this contribution: i) to perform HI and TSHI, and ii) to find opportunities for hot water production for district heating network. As the demonstration is performed to an industrial company, the data are regarded as confidential, and therefore the enthalpy flowrates are normalised in Efenis Site depending on the length of the x-axis and in TransGen by taking hot utility consumption from the targeted solution of condition 1 as a reference point. It should be noted that the shape of the curves are preserved.

3.1 Tools Integration

Two different tools mentioned previously are applied:, Efenis Site – especially suited to obtain targets under fixed operational conditions, and TransGen – suited to obtain targets, existing and modified designs under fixed and varying operational conditions. Data extraction for target designs of the whole industrial site implemented within Efenis Site are based on composite streams data by applying data extraction following the basic principles for HI (Klemeš et al., 2010). On the other hand, the data implemented within TransGen are extracted for each HE unit by segmentation of the process streams. The required data for analysis are stream contents, supply and target temperatures, specific heat and flowrates at hot and cold sides. The GCCs for target design within ThansGen is based on the stream segments data, it offers more precise solution (within 1 %) than in cases when it is based on composite streams data applying data extraction following the basic principles for HI. Both Efenis Site and TransGen take part of three-level tool integration, from the data acquisition tool (process simulator, spreadsheet etc.) to Pinch Analysis in Efenis Site and code optimisation in TransGen, to graphical and numerical output - see Figure 2.

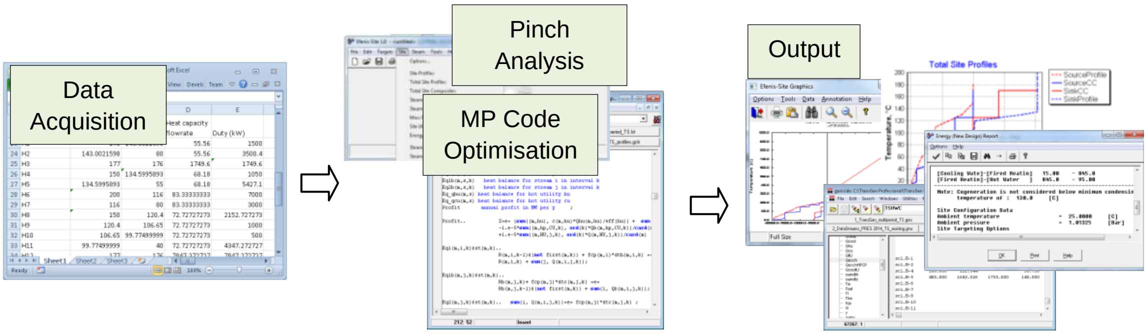

Figure 2: Example of three-level tool integration within Efenis Site and TransGen

3.2 HI and TSHI Under Fixed Operational Conditions

First HI and TSHI under fixed operational conditions are performed using Efenis Site for condition 1. The standard procedure has been applied for this purpose (Klemeš et al., 2010). Figure 3 shows GCCs for each unit. The targeting results show the theoretical maximum energy recovery opportunity with ideal usage of external hot and cold utilities, and production of intermediate utilities. Site-wide utilities are furnace heating, high pressure steam (HPS), medium pressure steam (MPS), low pressure steam (LPS), hot water, hot oil, cooling water and air cooling. The minimum allowed temperature difference has been assumed for the preliminary study as ΔT_{min} = 5 °C. There are significant energy savings opportunities when comparing to the real energy requirements and are for units 1 and 2 which are further analysed for varying operational conditions:

- Unit 1: hot utility savings of about 11.1 %, cold utility savings of 100 %;
- Unit 2: hot utility savings of 0 %, cold utility savings of 0 %, only utility generation could be corrected.

Figure 4 shows TS Profiles and Site Utility Composite Curves (CCs) without and with district heating. It can be seen that there is a potential to additionally reduce the heating and cooling requirements for about 15 % and 24 %. In addition to TSHI it is assumed that certain amount of hot water should be produced for district heating, which can be satisfied as shown in Figure 4. The amount of hot water production exceeds the amount which could potentially be sold for district heating.

3.3 HI and TSHI Under Varying Operational Conditions

HI and TSHI are further performed under for varying operational conditions only those two units are taken

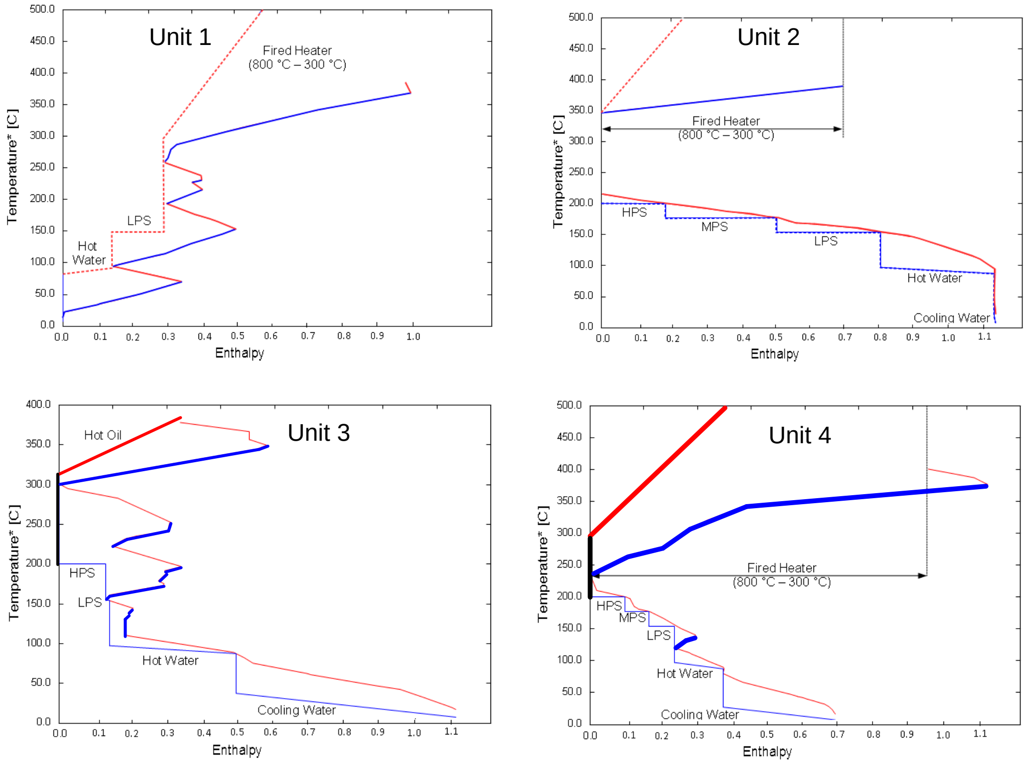

Figure 3: GCCs showing target designs for units 1 – 4

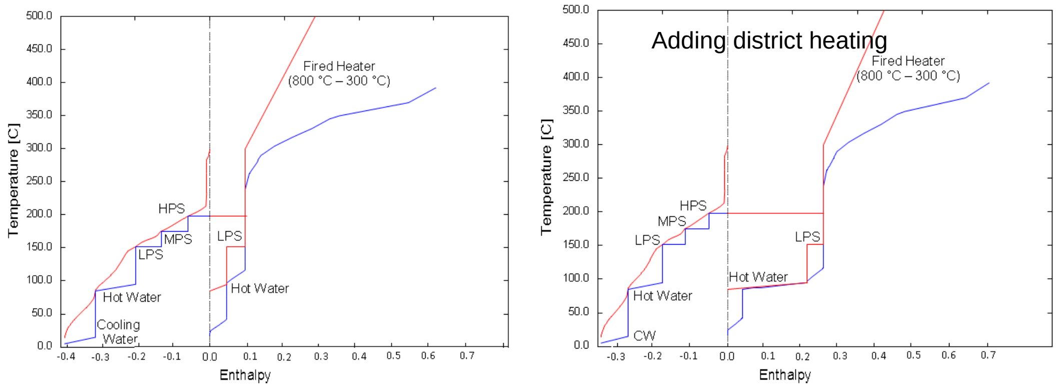

Figure 4: TS Profiles and Site Utility CCs without and with district heating

into consideration for HI and TSHI under varying conditions. Integrations are performed using framework TransGen. The data to be used within TransGen are extracted for each HE unit by the segmentation of process streams. Targeted designs are obtained by relaxing all the restrictions to existing HEs, whilst current designs when all the restrictions are imposed. The maximum possible scope for retrofit modifications is marked with ↔ in the following Figures. Besides reduction of external utilities also intermediate utilities could be produced. It should be noted that as GCCs for targeted design are based on the stream segments data, they offer slightly more precise solutions (within 1 %) than in those cases when they are based on composite streams data applying data extraction following the basic principles for HI.

Figure 5 shows GCCs for a) target and b) existing designs for unit 1 under all four varying conditions. Similarly, Figure 6 shows GCCs for unit 2 for both designs. The darkest curves represent condition 1 and the brightest represent condition 4. As it can be seen considering varying conditions gives rise to solutions expressed in ranges – hot utility consumption in unit 1 could be reduced from 5.6 % (condition 2) to 22 %

(condition 3), whilst cold utility almost decreases to zero. Regarding the unit 2 it could be seen that there neither hot nor cold utility consumption could be reduced. However, on the other hand more valuable intermediate utilities may be produced.

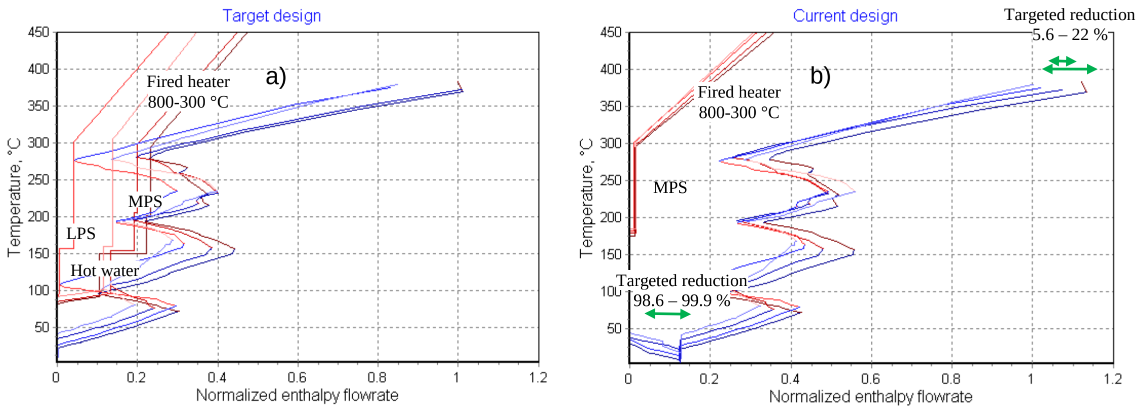

Figure 5: GCCs for a) target and b) existing designs under varying conditions for unit 1

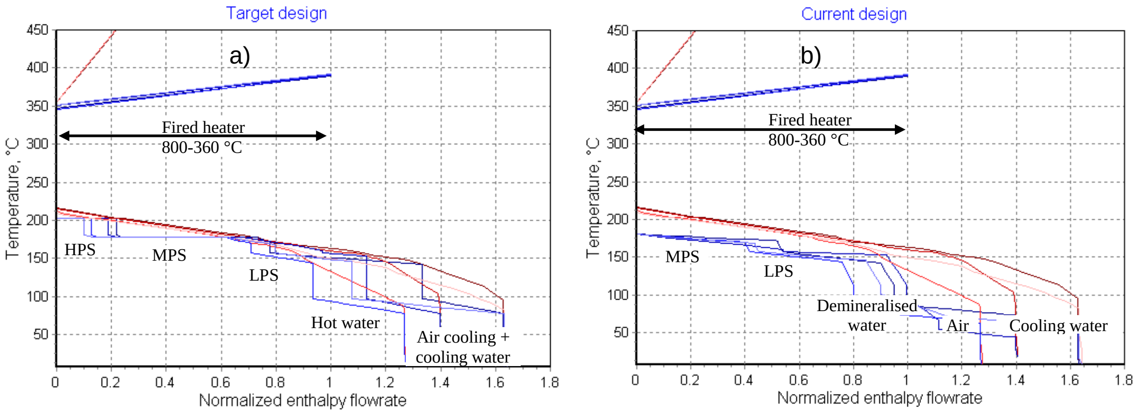

Figure 6: GCCs for a) target and b) existing designs under varying conditions for unit 2

Finally, Figure 7 shows TS Profiles under four varying conditions. They are obtained using indirect integration via intermediate utilities at four levels. The same steam mains as exist within the company are used for indirect integration. Via steam mains significant amount of energy is transferred, between 11 % (condition 4) and 25 % (condition 1) in regards to external hot utility consumption. Also, there is possibility of producing the hot water for district heating as it could be seen from Site Source Profiles.

4. Conclusions

This contribution presents data acquisition for Hi and TSHI under fixed and uncertain operational conditions. Efenis Site software has been efficiently applied to it under fixed conditions and the developed framework TransGen under varying conditions. The procedure for data acquisition and TSHI is illustrated on a demonstration case study of an existing petrochemical plant. More accurate results as from conventional data extraction have been obtained by TransGen as they now rely on more precise segmented stream data. The scope for energy reduction and intermediate utility production is presented at plant and TS levels. This procedure is going to be further extended to the pre-screening stage of HEN retrofit modifications and further to several additional features, such as investigations of the trade-offs between the investment and operating cost, pipeline layout and design, heat losses and insulation, pressure losses and pumping etc.

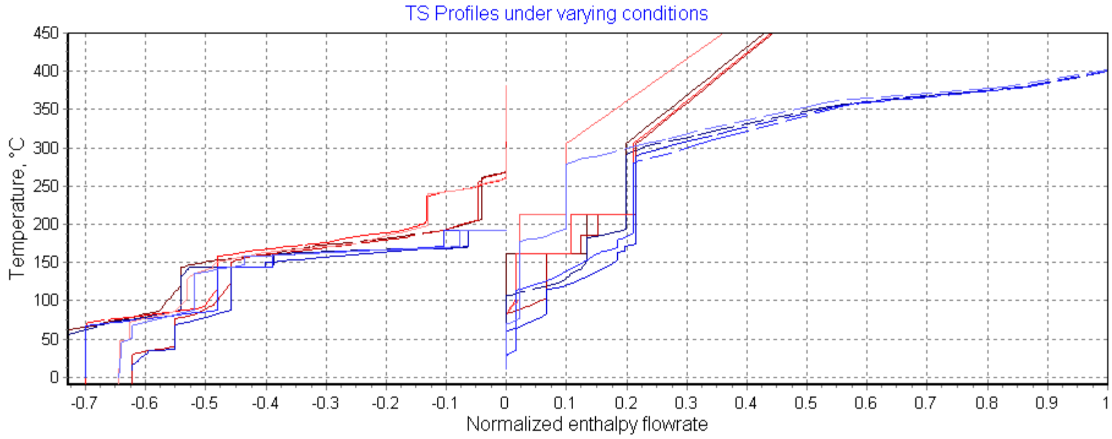

Figure 7: TS Profiles under varying conditions for units 1 and 2

Acknowledgments

The authors acknowledge the financial supports from EC FP7 projects ENER/FP7/296003/EFENIS 'Efficient Energy Integrated Solutions for Manufacturing Industries – EFENIS', from Slovenian Research Agency (programs P2-0032 and P2-0377), and from the Greek-Hungarian Bilateral Program under project Greek General Secretariat for Research and Technology (GSRT) / European Regional Development Fund (ERDF) No HUN88/TET_10-1-2011-0539. The authors are also grateful to EFENIS partners Dr Igor Bulatov and Dr Li Sun from University of Manchester and Prof Vincenzo G. Doví from University of Genoa.

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