Special section: Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction – PRES 2014

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3 August 2015
Available online 24 August 2015

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1. Introduction

Energy is the life blood of every economy. Its demand grows or decreases with the level of economic activity. However, in any of these cases it is a necessary enabling ingredient for any recipe for economic and social success. The key factors contributing to success include the efficient sourcing, supply and use of energy carriers, where the efficiency concerns both the thermodynamic and economic aspects.

The goals of many countries include increased welfare and quality of life of their populations. When this is combined with the still rising population size, the total energy demand is expected to grow as a general trend. When considered together with the cost and climate concerns, there has been an apparent drive to reduce exploitation of traditional (fossil) energy sources, which has increased the importance of energy saving and it is nowadays a key-target for companies and countries. In this context, the evolution of the primarily fossil energy base towards a higher share of renewable sources also plays a prominent role.

Reflecting on these societal needs, PRES 2014 has been a venue for researchers, practitioners and students for presenting their research results, ideas, requirements in a well structured programme of lectures, poster sessions and discussions, providing a platform for scientific and engineering networking. The activities taking place include review of the latest development and applications in the fields of Process Integration, mathematical modelling and optimisation for energy conservation, pollution reduction and related topics leading to sustainable, environmentally friendly and cleaner production. Discussions of industrial experience and applications of energy saving and pollution reduction methodologies have been especially welcome. Another important activity during the conference has been the exchange and conception of new ideas and even projects.

PRES 2014 [1], held 23–27 August 2014 in Prague – the Czech Republic, was the seventeenth venue in the series of conferences initiated in collaboration with Professor Zdeněk Burianec in 1998. Since that time, the congress has been held in collaboration with CHISA – Prague on every even-numbered year. On odd years PRES has been organised in other places – in association with other world leading scientific meetings such as the ESCAPE in Budapest, Hungary, in 1999, in Florence, Italy, with ICheaP in 2001, in Hamilton, Ontario, Canada, with CSChE in 2003, in Giardini Naxos, Taormina, Italy, in 2005, in Ischia in 2007, in Roma in 2009 and again in Florence, Italy in 2011, all with ICheaP.

The PRES 2014 conference has attracted 551 abstracts, prepared by 2133 authors from 57 countries. From those the Scientific Committee selected 216 oral presentations, 33 being keynote, and 4 plenary lectures common for PRES and CHISA, and 233 posters. The following section provides a concise introduction into the topics discussed by the papers in the Special Issue, followed by overview of each of the articles.

The current Special Issue, continues the established tradition of very successful and long lasting collaboration between the ENERGY journal and the PRES conference, which can be traced back to 2006

[2], to the Special Issue from the PRES 2004 conference. The publication policy of PRES conferences involves also collaborations with other related journals such as Applied Thermal Engineering [3] or Clean Technologies and Environmental Policy [4].

2. Overview of the articles

The Special Issue includes contributions dealing with efficiency improvement and reduction of harmful emissions, which focus on heat utilisation and valorisation, followed by works on Heat and Resource Integration, Process Improvement and Intensification, Energy and Production Planning, Supply Chains, Large Scale and Regional Optimisation.

2.1. Heat utilisation and valorisation focus

Industrial sites are hierarchically organised in sites, processes and operating units. Each of these levels offers a possibility to investigate the energy integration with different techniques and methodologies. Especially in the recent years, the optimisation for waste heat utilisation, including the low temperature and low potential heat, has intensified resulting in a variety of investigations at levels varying from the process scale to the total site or inter-site (area-wide) scale, involving several sites of different type. Several articles in this Special Issue offer new insights and industrial studies taken from the practice.

The work by Oluleye et al. [5] presents a ranking criterion for evaluating the opportunities on an industrial site that utilise recovered energy from available waste heat sources. The criterion takes into account the energy performance of waste heat recovery technologies associated with each opportunity and their potential to reduce greenhouse gas emissions. A methodology to use the ranking criterion for designing waste heat recovery systems for Total Site – conceived by Dhole and Linnhoff [6] and completed by Klemeš et al. [7], is also proposed in the paper and applied to a petroleum refinery. The provided illustration examples demonstrate the applicability of the method and show that notable energy savings can be achievable by using it.

The work by Liu et al. [8] investigates the use of genetic algorithms to carry out energy and exergy analyses at the process scale. The genetic programming is applied to a sinter cooling bed by means of a bi-objective optimisation to achieve the optimal operation conditions from the view points of waste heat utilisation and cost, using a non-dominated sorting genetic algorithm. The study shows that energy and cost savings, achievable by applying the optimisation, can reach the order of 10^6 GJ/y and 10^5 USD/y.

At the process scale the attention is mainly focused on the conversion and reuse of low temperature/low potential waste heat; a huge amount of waste heat, for instance, needs to be cooled to the ambient temperature in refineries. ORC (Organic Rankine Cy-cles) are widely used in low temperature waste heat recovery, but the selection of working fluid and operating conditions exert significant influence on the ORC performance. A new method is proposed by Yu et al. [9] to simultaneously determine the working fluid and operating conditions in an ORC system. The method is based on the definition of a new parameter able to accurately predict the Pinch position between the waste heat carrier and the working fluid, calculate easily the mass flow rate of working fluid and the amount of heat recovered, and determine the optimum working fluid and its corresponding operating conditions. The authors point out that compared with previous works in which working fluid selec-tion and parameter optimisation were conducted separately, this paper can determine the working fluid and operating conditions simultaneously.

Boldyryev and Varbanov [10] studied the energy efficiency of bromine production site for heating and cooling demands reduction. The Pinch Analysis [11] in this case is used in combination to the Total Site assessment for the estimation of energy saving potential and design of retrofit project at the plant-wide scale. The study has indicated w that the process with improved heat integration consumes can save more than the half of hot utility of the site. The authors conclude that the approach is clearly transferrable to other types of chemical industry sites.

2.2. Heat and resource integration

The part of the Special Issue on Heat and Resource Integration features three articles dealing with heat/energy saving and hydrogen in refineries.

Heat Integration across plants, or better still at the area-wide level, is an extension of conventional Heat Integration in a single plant for further improving energy efficiency. To make good use of surplus heat, indirect Heat Integration pattern using intermedi-ate fluid loops and direct heat integration pattern using process streams are proposed to exchange heat across plants. Two integration patterns – direct and indirect, are possible, where it is difficult to decide in advance which one is more beneficial, because each of the patterns fits different practical situations. Wang and Feng [12] propose a combined Heat Integration method, which involves the characteristics of both the direct and the indirect patterns. They also propose a new mathematical model and use Composite Curves visualisation to identify the integration pattern and the optimal operation conditions for each pattern. The authors indicate that the newly proposed combined methods is able to achieve lower to-tal annualised costs by up to about 13% compared with the individ-ual approaches.

Deng et al. [13] present a systematic method for targeting the inter-plant, site-wide hydrogen network with direct and purification reuse/recycle schemes. Two scenarios of interplant hydrogen integration with direct reuse/recycle are investigated. The case study shows that the conservation ratio of the flow rate of hydrogen utility in a scenario is greater than or equal to the competing sce-nario and that with purification reuse/recycle scheme is increased sharply. The energy performance evaluation by the authors shows that the plant-wide hydrogen integration offers very significant improvement of the equivalent energy consumption, amounting to several-fold increase in the energy savings.

Matsuda et al. [14] have performed Total Site optimisation [15] at the Map Ta Phut industrial area, one of the biggest chemical com-plexes in Thailand. This area was considered not to have potential for any further energy saving because their designs have been opti-mised for energy efficiency. However, further improvements of the energy efficiency have become necessary, in order to increase the international competitiveness of the area and its contribution to preventing global warming. To achieve the further energy saving, the concept of “area-wide approach” was applied to this area to develop an area-wide energy saving program, which was composed of a number of collaborative energy saving projects across sites. The authors indicate that the site may reach up to 29% energy savings within the considered area.

2.3. Process improvement and intensification

This section presents four articles related to various process-level improvements. These range from energy savings, to integration of renewable energy, CO_2 capture and to Process Intensification.

Walmsley et al. [16] present a thermo-economic design optimisation of an industrial milk spray dryer liquid with the coupling of the loop exhaust heat recovery system. Incorporated into their analysis is the ability to predict the level of milk powder fouling over time and its impacts on heat transfer and pressure drop. Modelling results show that spray exhaust heat recovery is economically viable for the considered industrial case study, indicating an internal rate of return of 71%. The authors envisage that the proposed model has flexibility to be applied to any milk powder plant to optimise the economics of an exhaust heat recovery system.

Perevertaylenko et al. [17] have turned their efforts to maximising the cost efficiency of amine-based operating units for CO_2 capture. The currently used post-combustion capture method based on MEA (monoethanolamine) absorption without stream split has significant steam consumption to regenerate the amine solution. In this work, the HEN ADU (Heat Exchanger Network of an Absorption Desorption Unit) is analysed using the Process Integration methodology. The analysis has evaluated the process for finding economically viable options of desorption column parameters by computer modelling and the use of compact PHEs (plate heat exchangers) with intensified heat transfer. The authors report that with economically efficient use of PHEs it is possible to decrease energy consumption in the carbon dioxide post combustion capture unit by up to 24%, compare to 11% with traditional shell and tube heat exchangers. It is possible even with the investment costs smaller on 10–15%.

Another contribution from New Zealand, authored by Walmsley et al. [18] deals with renewable energy integration into food production. The specific configuration studied involves the use of solar thermal energy for supplying heat recovery loops. The authors put forward the idea that Heat Integration of solar thermal energy into low temperature Pinch processes, like dairy and food and beverage processes, is more economic when combined with a heat recovery loop to form a combined inter-plant heat recovery and renewable energy utility system. Among the discussed benefits are common infrastructure such as piping, pumping and storage, and improved solar heat utilisation through direct solar boosting of the loops intermediate fluid temperature and enthalpy. The results reported indicate that the best location for integrating solar heating is in series with the heat sources as the hot fluid returns to the storage tank.

Heat recovery is more and more often sought within processes by applying combined intensification-integration techniques [19]. Kansha et al. [20] investigated the application of self-heat recuperation technology to the process of dimethyl ether production, leading to an innovative process configuration from an energy saving point of view, considerably reducing the energy consumption of the thermal and separation processes. Dimethyl ether is commonly produced by two methods: indirect and direct DME synthesis. In the proposed method, methanol is produced first and then converted to DME. In the direct method, DME is directly synthesised from syngas without passing through any methanol production. From the shown results it is indicated that the new process configuration offers up to 80% reduction in thermal utility demands at the expense of using a certain amount of power.

2.4. *Energy and production planning*

The energy aspects of process and industrial sites planning have been investigated as well. This section presents two articles dealing with load shifting as an energy management strategy and power generation planning.

Rozali et al. [21] studied the electricity load distribution throughout the day depending on the time of operations of equipment and processes and the ambient weather conditions. They applied Power Pinch Analysis [22] to guide load shifting aimed at reducing the electricity maximum demand. The results of their work show that the total outsourced electricity during the peak hours can be successfully distributed to the off-peak hours to minimise the electricity cost. The authors recommend that the future research focuses on the sizing of the storage capacity.

In planning the operation of waste-to-energy plants one has to account that they are in many cases generators of both power and thermal energy, – classified as CHP (combined heat and power) producers. Touš et al. [23] present a simulation based support for such plants including models for boilers and steam turbines extended to the stochastic/Monte Carlo simulation to handle uncer-tainty and fluctuations. Benefits in terms of net thermal efficiency and increased revenue are proven through a comparison using real operational data. The authors report that, compared to the cur-rent planning strategy in the studied plant, the stochastic simula-tion based planning provides increased CHP capacity resulting in better net thermal efficiency and increased revenue. This has been demonstrated through a comparison using real operational data.

2.5. *Supply chains, large scale and regional optimisation*

The improvement of efficiency and economic viability is important not only at the process and site level. Important opportunities can be found also at higher levels and scales of integration. This part of the Special Issue presents three articles geared towards explora-tion and evaluation of such larger-scale configurations.

Holmgren et al. [24] have prepared a study on the supply chain analysis for biomass-based SNG (Synthetic Natural Gas) accounting for the greenhouse gas emissions. The impact of the supply chain on the emissions has been analysed by assessing GHG emissions of locally produced woodchips and pellets with regional or transatlantic origin for the context of Sweden. The results presented by the authors indicate that the supply area for the gasification plant can be substantially increased with reasonable increases in overall GHG emissions (3–5%) based on locally sourced biomass, while the overseas pellet delivery results in significantly (more than 20%) higher GHG emissions.

Another study from Sweden has been provided by Hackl and Harvey [25], who have attempted to propagate the Total Site Analysis techniques [26] and approach at the level of industrial clusters. As a major additional development they have formulated the need to develop the Total Site Analysis methodology further, in order to enable identification of practical heat integration measures in a sys-tematic way. The authors present a method for designing a road-map of heat integration investments based on total site analysis, where they put a strong emphasis on increasing the collaboration among the plant managers. The method has been applied to an in-dustrial cluster in Sweden. The reported results show that the application of the proposed method allows saving up to 42% heat recovery at paybacks of maximum 3.9 y.

Hierarchy and performance of waste heat utilisation opportunities depends on the temperature of the heat available, amongst other factors. Concerns related to climate change and security of energy supply are pushing various countries to make strategic energy planning decisions at the Total and Region wide scale. This requires the development of energy models to aid decision-making. Large scale energy models are often very complex and use economic optimisation to define energy strategies. They might be black-boxes to public decision-makers. The work by Girones et al. [27] aims at overcoming this issue by proposing a new modelling framework, designed to support decision-makers by improving their understanding of the energy system. The goal is to show the effect of the policy and investment decisions on final energy consumption, total cost and environmental impact. Final energy consumption is represented as the sum of three main components: heating, electricity and transportation. The approach has been implemented in an online energy calculator for the case of Switzerland.

3. Conclusions and acknowledgements

This Editorial of the Special Issue devoted to PRES 2014 conference provides an overview of the contained articles to serve the readers as a guide to exploring the discussed ideas and methods. The topic coverage is important and wide ranging, covering issues from the process level up to regional scale in one dimension as well as process improvement, intensification, integration and supply chains in another key dimension. The Guest Editors believe that the papers would be useful to the readers of the ENERGY journal, as has always been the result of the productive collaboration between ENERGY and the PRES series of conferences. Especially heartfelt thanks are expressed to all the reviewers who have made most valuable contributions by reviewing, commenting and advising the authors. Special thanks go to the administration staff in the ENERGY journal for their excellent support, in particular to the Journal Managers Dhilip Kumar Perumal and Emily Wan.

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