A Graphical Method for Simultaneous Targeting and Design of Multiple Utility Systems

MOHSEN CHEZGHANI

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I dedicated this entire work to my beloved mother and father and who always be my side
For all their selfless love, supprt, inspiration and encouragement…

Thanks…

ABSTRACT

Multiple utility targeting has been one of the most important steps in process integration and has direct effect on total cost. Indeed, the majority amount of investments in any plant especially chemical plant is allocated for supplying hot and cold utilities. Regarding to this fact having realistic design to show the exact amount of the minimum hot and cold utility has been serious concerns among designers and plant owners. Composite Curves (CCs), Grand Composite Curves (GCC), Balanced Composite Curves (BCC) and Balanced Grand Composite Curves (BGCC) have been the common graphical tools to achieve this aim. The current graphical methods may have acceptable results in terms of energy targeting. However, these tools cannot offer sufficient guidance for individual stream matching which is vital to have realistic surface area targeting as well as multiple utility targeting. This research presents a new graphical method for simultaneous targeting and design of multiple utility systems based on stream temperature versus enthalpy plot (STEP) method. Systems including variable-temperature utilities (Flow Gas, Cooling Water) are considered and some limitations of current graphical method (CCs, GCC, BCC, BGCC) have been highlighted. In addition, some examples are provided to demonstrate different limitations of mentioned graphical tools in terms of utility targeting and minimum surface area targeting. The presented method is more realistic as compared to the current graphical methods and can helps designers to have better understanding of multiple utility systems including variable-temperature utilities as well as constant-temperature utilities.

ABSTRAK

Kaedah mensasarkan utiliti pelbagai kian menjadi salah satu langkah yang penting dalam proses integrasi dan ia mempunyai kesan langsung ke atas jumlah kos. Malah sebahagian besar peratus pelaburan dalam sebuah loji terutamanya loji kimia adalah untuk membekalkan utiliti panas dan sejuk. Maka, berikutan fakta ini, mempunyai reka bentuk yang realistik untuk menunjukkan jumlah sebenar utiliti minimum yang panas dan sejuk telah menjadi kebimbangan serius di kalangan pereka dan pemilik loji. Lengkung Komposit, Lengkung Komposit Besar and Keluk Komposit Seimbang telah menjadi alat grafik yang lazim untuk mencapai matlamat ini. Kaedah grafik semasa boleh memberi keputusan yang boleh diterima dari segi mensasarkan tenaga tetapi ia tidak boleh memberikan panduan yang cukup bagi penyesuaian aliran individu yang amat penting untuk memberi sasaran luas permukaan yang realistik serta sasaran utiliti pelbagai. Untuk memperoleh sasaran luas permukaan dan untuk mengetahui aliran proses padankan terhadap tahap dan jenis utiliti, suhu masuk dan suhu alur untuk aliran setiap individu diperlukan yang tidak boleh diperolehi daripada keluk komposit. Dalam kajian ini, beberapa batasan kaedah graf semasa telah diserlahkan. Penyelidikan ini membentangkan kaedah grafik yang baru untuk penyasaran serentak dan reka bentuk sistem pelbagai utiliti yang berdasarkan suhu arus melawanentalpi plot(STEP). Di samping itu, beberapa contoh disediakan untuk menunjukkan pelbagai batasan bagi Lengkung Komposit, Lengkung Komposit Besar serta Keluk Seimbang Komposit dari segi mensasarkan utiliti dan luas permukaan minimum. Kaedah yang dibentangkan adalah lebih realistik berbanding kepada kaedah grafik semasa dan boleh membantu para pereka mendapat pemahaman yang lebih baik sistem terhadap utiliti pelbagai termasuk suhu ubah utiliti serta suhu malar utiliti.

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Nomenclature

A_{min}	Minimum Network Area
ADP	Acid Dew Point
BCC	Balanced composite curves
BGCC	Balanced grand composite curves
C	Cold stream
CCs	Composite Curves
CGCC	Cumulative grand composite curves
CW	Cooling Water
CHP	Combine Heat and Power
FCp	Heat capacity flowrate (kW/◦C)
FG	Flue Gas
GCC	Grand Composite Curve
H	Hot stream
HE	Heat exchanger
ΔH	Enthalpy change (kW)
HEAT	HEat Allocation and Targeting
HPS	High Pressure Steam
HEX	Heat Exchanger
IEO	International Energy Outlook
IPTA	Improved Problem Table Algorithm
LPS	Low Pressure Steam
MHA	Maximum Heat Allocation
MPS	Middle Pressure Steam
OECD	Organization for Economic Cooperation and Development

PTA	Problem Table Algorithm
PDM	Pinch Design Method
Q	Heat duty (kW)
QC	Cooler
QC,min	Minimum cold utility (kW)
QH	Heater
QH,min	Minimum hot utility (kW)
STEP	Stream Temperature vs Enthalpy Plot
T_{pinch}	Pinch temperature (◦C)
′	Supply temperature (◦C)
′	Shifted supply temperature (◦C)
T_t	Target temperature (◦C)
ΔT_{min}	Minimum temperature difference (◦C)
TLP	Temperature Limiting Point
ULP	Utility Limitation Profile
USL	Utility Stream Line

CHAPTER 1

INTRODUCTION

1.1 Background

Energy is fundamental in industrial economies and yet is often overlooked in the drive for profitability. Recent energy-market developments, increasing oil and gas prices, as well as the effect of combustion gas on climate change (CO_2 is a greenhouse gas), have enhanced the emphasis on energy management. Plant owners are seeking alternatives for fossil fuel or ways to reduce energy and consumption of other utilities in order to minimize utility costs as well as maximizing profitability. In energy management, process integration based on pinch technology is one of the ways to reduce utility consumption in a systematic way based on thermodynamic rules.

1.2 Outlook on energy

From international energy outlook 2010 (IEO, 2010), world market energy consumption is projected to grow by 49 % from 2007 to 2030. The total energy required in non-OECD (Organization for Economic Cooperation and Development) countries has risen by 84 percent, whereas, the increase in OECD countries is just around 14 %. The total world energy use is predicted to increase from 495 quadrillion (Btu) in 2007 to 590 quadrillion Btu in 2020 and 739 quadrillion Btu in 2035. (U.S. Energy Information, 2010) (see, Figure 1.1).

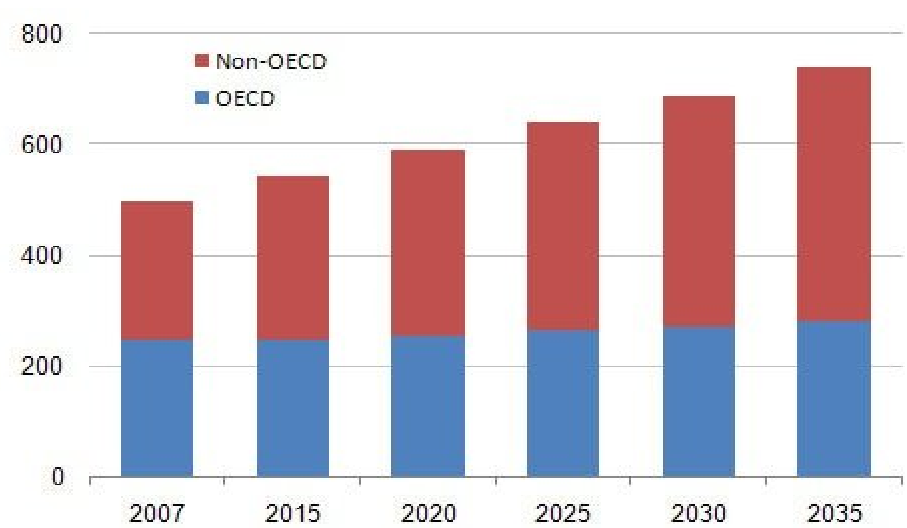

Figure1.1 World market energy consumption by region, 2007 – 2035 (U.S. Energy Information, 2010)

Based on data from the International Energy Outlook (2010), about one-half of the world's total delivered energy is consumed in industrial sector and close to two-third of this amount of energy are used for heating and cooling as well as for powering equipment in plants. Over the 28-year projection, worldwide industrial energy consumption grows from 184 quadrillion Btu in 2007 to 262 quadrillion Btu in 2035.

The notable point is that around 50% of all energy produced in the world is used in only five industrial sectors (Figure 1.2). Chemical industries by 22% use maximum amount of energy among surveyed sectors which is followed by iron and steel 15%, nonmetallic minerals by 6%, pulp and paper 4% and the minimum percentage belongs to nonferrous metals by just 3%. The quantity and fuel mix of future industrial energy consumption will be determined largely by energy use in those five industries. In addition, the same industries emit large quantities of carbon dioxide, related to both their energy use and their production processes.

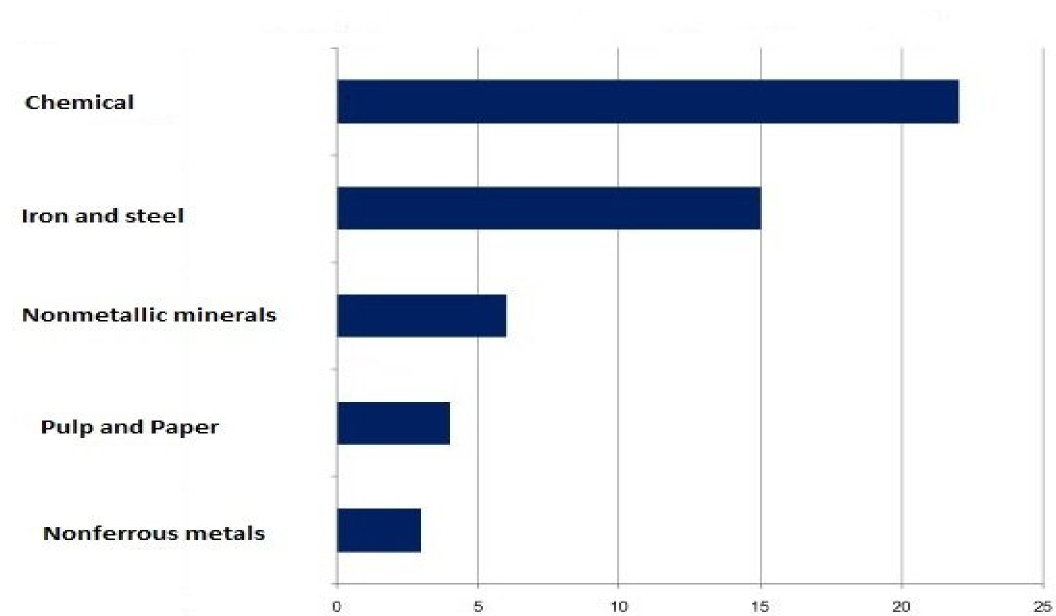

Figure 1.2 World industrial sector energy consumption (percent of total) by major energy intensive industry shares in 2007. (U.S. Energy Information, 2010)

1.3 Problem Background

For many years, plant designers have applied graphical tools to obtain the best combination of available utilities. The Grand Composite Curve (GCC) has been one of the most common graphical methods to achieve this aim. The GCC is a plot based on problem table algorithm (PTA) or composite curves (CCs) information. Since CC and GCC methods involve combining individual streams as composite streams, it is difficult to graphically match and allocate the utilities with individual process streams. Hence, in this research, it is proposed to use individual curve method to solve this and use it to represent all multiple utilities and area targeting method that have been proposed based on composite nature.

Some limitations of composite curves are listed below (Wan Alwi and Manan, 2010):

1. Heat exchange between individual cold and hot streams cannot be represented, completely.
2. Insufficient guidance is offered in terms of individual stream matching.
3. Composite curves cannot be used for designing heat exchanger networks.
4. The minimum heat exchanger area and the optimum ΔT_{min} cannot be obtained correctly due to the use of composite streams instead of individual streams.
5. The integration between utilities and each process streams cannot be conveniently demonstrated.

1.4 Problem statement

Given a process that involves a set of hot and cold streams, it is required to develop a graphical approach to simultaneously target and design a maximum heat recovery network with the appropriate utility levels and type, stream matches and possible process modifications that can yield the minimum cost in terms of utilities and heat exchanger area costs. The graphical approach should be able to consider individual stream matches between process to utility streams and in particular, taking into account of utilities with variable supply and target temperatures.

1.5 Objective

The main objective of this research is to develop a new graphical approach for simultaneous targeting and design of multiple utility systems. The key focus of the work is the development of new techniques to interface individual process-utility systems with variable supply and target temperatures.

1.6 Scope of the Study

1. Analysis on current graphical tools for multiple utilities targeting and highlighting their advantages, disadvantages and limitations.

2. Develop a graphical tool for simultaneous heat exchanger network targeting and design with multiple utilities level.

3. Comparing the new developed graphical method with current graphical methods in term of result reliability.

4. Assessing the new developed method and state the overall its advantages and disadvantages.

5. Discussing about probable drawbacks of the new developed method and suggest some solutions to improve and modify it in the future works.

1.7 Research Contributions

The research contribution in this study is to assess the current graphical methods in terms of utility targeting as well as stream matching and to find out their limitations. Moreover, the main contribution in this work is the development of a new graphical approach and heuristics (guidelines) for simultaneous targeting and design of heat exchanger network with multiple utility levels.

1.8 Summary of the Thesis

This thesis consists of 5 chapters as follows:

1) Chapter 1 presents an outlook on the worldwide demand of energy, the research background,the main reseach objective, research scope and the importance of the research.

2) Chapter 2 reviews the previous research and approaches on graphical tools in terms of multiple utility targeting and the minimum area targeting.

3) Chapter 3 illustrates the concepts and detailes of methodology based on the new method.

4) Chapter 4 presents results of this study and some limitations of current graphical methods has been considered through three diffenent case studies.

5) Chapter 5 presents conclusion on resuls of this research and offers some recommendations to improve limitations of the proposed method.

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