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Development of an energy management system for a naphtha reforming plant: A data mining approach

David Velázquez [a], Rocío González-Falcón [a,*], Luis Pérez-Lombard [a], L. Marina Gallego [a], Iñigo Monedero [b], Félix Biscarri [b]

[a] School of Industrial Engineering, Energy Engineering Department, University of Seville, Camino de los Descubrimientos s/n, 41092 Seville, Spain
[b] School of Computer Science and Engineering, Electronic Technology Department, Av. Reina Mercedes s/n, 41012 Seville, Spain

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ABSTRACT

Despite the industrial sector accounts for about a quarter of total final consumption worldwide and great efforts have been carried out to reduce its energy use in the last decades, there are still substantial opportunities to improve industrial energy efficiency. Among those opportunities, energy management systems (EMSs) are one of the most successful and cost-effective ways to significantly reduce energy use, energy costs and environmental impact without affecting production and quality. This paper describes the development of an energy management system for a naphtha reforming plant by the use of a data mining approach. The paper shows how these techniques have been applied to identify key influence variables on energy consumption and to develop an energy performance model of the plant. Energy baseline and energy targets have been derived for the assessment of achieved and potential energy savings. Plant results show how savings may be achieved after the implementation of the EMS by tracking and adjusting performance against energy targets.

1. Introduction

Industry is a significant energy end-use sector comprising 27% of the world's total final consumption in 2009 [1]. Energy-intensive industries (bulk chemicals, refining, paper products, iron and steel, aluminum, food, glass, and cement) dominate industrial energy demand, accounting for nearly two-thirds of industrial delivered energy consumption [2]. Additionally, worldwide projections on industrial energy consumption predict a growing trend over the next 25 years with an annual average rate of 1.5% [3]. However, substantial opportunities to improve industrial energy efficiency have been shown by the International Energy Agency (IEA) [4], and much of this potential can be captured through policies for the promotion of the implementation of energy management systems (EMSs). In this sense, the IEA has advised governments to require high energy-intensive industries to comply with ISO 50001 [5] or an equivalent energy management protocol.

Refining is a high-consuming industry, accounting for about 7% of total energy consumption in US in 2002 [6]. A large variety of opportunities exist within petroleum refineries to reduce energy consumption while maintaining or enhancing productivity, as clearly shown by competitive benchmarking data indicating that most refineries can economically improve energy efficiency by 10–20% [7]. Particularly, implementing EMS is one of the most successful and cost-effective ways to bring about energy efficiency improvements.

Energy management aims to minimize energy costs and environmental impact without affecting production and quality [8] by the achievement of continuous improvement of energy performance, energy efficiency and energy conservation. Energy performance indicators (EPIs) should be identified to assess energy performance and to subsequently evaluate progress towards objectives and targets. Thus, measuring baseline performance, setting goals and tracking performance against those goals are the keystones of every EMS [9].

Industrial patterns of energy use are complex, especially when production rates are highly variable, when the product mix varies, or when several interacting processes coexist at a single site. Recently, the availability of massive performance data has increased the interest in the application of data mining to industrial energy management. Data mining is the process of extracting valid, new and comprehensive information from massive data in order to improve and optimize business decisions [10]. A multitude of methods are available for carrying out data mining procedures, however, within the industrial field, they focus on process monitoring and control, soft sensors, expert systems, fault detection and diagnosis [11]. Many industries have applied data mining by the use of statistical methods [12–14] and neural networks or decision trees [15–19]. In the last decade, the research on crude distil-

* Corresponding author. Tel.: +34 954 482283.
E-mail address: rgf@us.es (R. González-Falcón).

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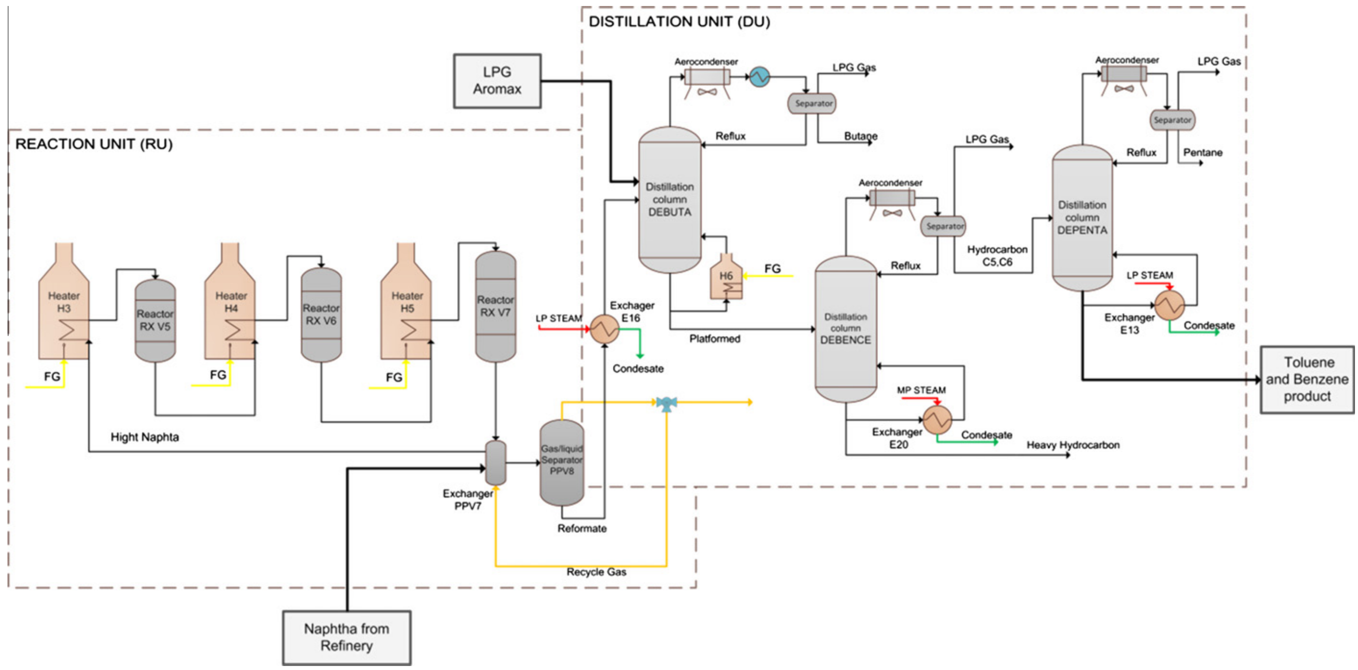

Fig. 1. Process flow diagram of the platforming unit.

Table 1
Annual energy consumption by energy source and unit.

Unit	Energy source	Equipment	Energy use (GWh/year)	Energy use (%)
RU	Fuel gas	Heater H3	62.8	27
	Fuel gas	Heater H4	68.5	29
	Fuel gas	Heater H5	25.9	11
DU	Fuel gas	Desbutanizer Heater H6	37.6	16
	Med pres. steam	Desbencenizer Boiler E20	25.5	11
	Low pres. steam	Despentanizer Boiler E13	12.9	6
Total			233.2	

Fig. 2. Phases of a data mining project.

lation processes has put the focus on control and optimization. Data mining has also been applied to predict quality of distillation products [20,21] and to estimate the optimal operating conditions of distillation process [22]. However, data mining has not been used so far for the development of an EMS, despite energy management has been identified as a priority for energy optimization in refineries [23].

This paper presents the application of a data mining approach to the definition, development and implementation of an EMS in a naphtha reforming plant with the aim of assessing energy performance and evaluating progress towards efficiency targets. The paper shows the way to select the key influence variables for energy performance, to identify the best performing periods in the past in order to set energy performance targets for the future, and to develop a baseline model. The main contribution of the paper is the development of an EMS for a naphtha reforming plant that allows measuring baseline performance, setting targets and tracking energy performance against those targets.

The paper starts with the description of the naphtha reforming plant (Section 2) and the definition of EMS requirements (Section 3). Then, in Section 4, the research methodology is presented. Section 5 provides the main results of the application of the data mining approach to the naphtha reforming plant. Finally, concluding remarks, benefits and limitations of the research are discussed.

2. Naphtha reforming plant

This section briefly describes the platforming unit and analyses its energy structure in order to define the requirements for the implementation of the EMS.

Catalytic reforming of heavy naphtha is a key process in the production of gasoline. The major components of petroleum naphthas are paraffins, naphthenes, and aromatic hydrocarbons. The aim of catalytic reforming is to transform naphthas hydrocarbons with low octane to hydrocarbons with high octane. The chemical