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Optimal planning and infrastructure development for shale gas production

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ABSTRACT

Recently, there has been a significant interest to the development and exploitation of unconventional gas resources especially shale gas. Several places around the world have substantial shale gas reserves in regions that lack in the infrastructure needed for production and distribution. This paper presents a new mathematical programming approach based on disjunctive programming to account for complex logical relationships in the optimal planning of shale gas exploitation and infrastructure development in places without infrastructure for production, treatment, and distribution. Because of the variability in natural gas supplies and demands over time, a multi-period optimization approach is adopted over a certain time horizon, which includes Monte Carlo simulations to assess the associated volatility. The optimization approach accounts for the different components of the infrastructure, the production schedules, and the time-value of money to maximize the net present value of the infrastructure. The applicability of the proposed approach is shown through a case study in the Burgos basin located in the Northeast of Mexico and in the southern extension of the Maverick Basin in Texas. The results show attractive economic results for the exploitation and distribution of gas to satisfy the national demand.

1. Introduction

As a result of population growth and economic development, the energy consumption continues growing [1]. Important economic and environmental impacts for the increasing energy consumption have been identified [2]. According to recent estimates, the global energy consumption is projected to increase by 41% in two decades [3]. Therefore, there has been significant interest in emerging energy sources such as unconventional gas (shale gas, tight gas, coalbed methane gas) and renewable energy with the expectation that these resources will contribute significantly to the growing energy demands, as consequence it causes concerns about the potential adverse impacts [4]. The co-production of ethylene [5] has been analyzed to improve the profitability. The oil shale [6] can be used to produce liquid fuels via pyrolysis. Furthermore, the energy security has been widely studied [7]. In developing the supply chains of the emerging energy resources, optimization can provide the decision makers with powerful tools for strategic planning [8]. In this context, Gupta and Grossmann [9] presented an efficient strategic planning model for offshore oilfields. Santibañez-Aguilar et al. [10] developed an optimization model for planning supply chains associated with biofuels. Zhang et al. [11] proposed a multi-period mathematical programming model for the optimal planning of utility systems. For the specific case of shale gas production, planning must include the consideration for the use of substantial amounts of water used in hydraulic fracturing over a short period of time. Typically, 7500–49,000 m^3 of water are used to fracture each well [12]. Best and Lowry [13] quantified the potential effects due to the water extractions for the Marcellus shale play. Clark et al. [14] estimated the water consumption over the life cycle of a shale gas play. Furthermore, Vengosh et al. [15] presented a critical review about the associated risks in the shale gas operations. Yang et al. [16] developed a mixed-integer linear programming (MILP) model for the optimal planning of water use for shale gas production, and Lira-Barragán et al. [17] proposed a mathematical programing formulation for the optimal management of flowback water in shale gas production. Ikonnikova et al. [18] presented an evaluation for the profitability of a shale play. Kaiser [19] presented an economic analysis for the Haynesville shale play. Wejeimars [20] showed the importance of the geographical location for the shale gas production. Yuan et al. [21] reported a review for the shale gas production. Calderón et al. [22] incorporated financial aspects

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Research Article **Open Access**

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Dehydration of Ethanol by PSA Process with Pressure Equalization Step Added

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Abstract: In this work, the ethanol dehydration production process is carried out using the Mathematical Modeling Pressure Adsorption Process. A new model is suggested, it has two equalization steps, and is compared with the Industrial Pressure Swing Process operating cycle. An analysis of the effects of introducing the pressure equalization step is performed on four main response variables: purity, production, recovery and energy consumption and it is compared with the current cycle configuration operating in the industry. We used Aspen Adsorption for the valuation and simulation of the cyclic PSA process. We analyzed and processed the simulation results in Statgraphics Centurion to obtain optimum operating conditions for the process. This evaluation shows that purity decreases slightly, whereas recovery and production increase. The most important thing is that the energy consumption is reduced. These results clearly show that by modifying the operating cycle schema, optimum operating conditions also change. The optimization of the new cycle was executed considering as variables bed pressure, adsorption time and purging flow. We found that a smaller column is more productive for the equalization cycle than that of a 14m bed, which is optimal in the industrial cycle with a consequent reduction in adsorbent material.

Keywords: Ethanol Anhydrous, Pressure Swing Adsorption, Pressure Equalization

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1 Introduction

Currently, a major concern worldwide is the declining of fossil energy reserves and the environmental impact that its use has caused, thus, research and development of renewable energy sources have intensified in the last years. As transport is the main generator of greenhouse gases, a great effort has been directed towards producing biofuels, being ethanol the most promising alternative to be used as an additive or substitute for gasoline. Nowadays, ethanol is produced through several processes such as sugar-based raw materials (e.g. sugar cane), starch-based raw materials (e.g. corn) and biomass-based raw materials (e.g. agricultural residues such as corn stover and wheat straw). These technological processes are different from one another in their initial phase, but something they have in common is that they produce very diluted ethanol (6-10% wt), which needs to be dehydrated for use it as a gasoline additive. An ethanol-water mixture forms a minimum-boiling azeotrope ethanol composition of 95.6% wt at an atmospheric pressure of 78.15°C, limiting its dehydration by conventional distillation. As a result, a great deal of alternatives have been reported to produce anhydrous ethanol through azeotropic distillation, extractive distillation, vacuum distillation, extractive distillation with salt effect, pervaporation and adsorption [1-5]. The most common within the industrial scale is the extractive distillation with a solvent, but it is high energy-consuming.

PSA process was developed in the 1960s [6] and it was initially used as a technique to separate air particles, produce oxygen and nitrogen or to remove impurities from gases. In recent years, the interest in PSA has increased due to its low-energy consumption levels [7], and it has been used in the bioethanol industry. Skarstrom's cycle operates in two beds and each bed operates in two phases with similar time periods. The first phase is pressurization followed by adsorption, and the second one is depressurization followed by purge. Pressurization is carried out in the feeding step, while a portion of the produced flow is used to purge the bed. Since Skarstrom's cycle was introduced,

Chapter 4
Process Intensification in Heat and Mass Exchanger Networks

José María Ponce-Ortega

Abstract This chapter presents the use of process integration as a useful tool for intensifying processes. Particularly, mass and heat integration through the synthesis of mass and heat exchanger networks represent powerful tools that can be used for reducing the need of external agents such as fresh water and hot and cold utilities. Two optimization formulations are presented for mass and heat integration and the application to two case studies shows significant savings of external utilities.

4.1 Introduction

In recent years, when unified processes are required to be competitive in the global market, process intensification has become a very exciting topic [1]. In this way, process intensification has been defined by Ponce-Ortega et al. [2] as any activity that involves one of the following points:

(a) Smaller equipment for given throughput.
(b) Higher throughput for given equipment size or given process.
(c) Less holdup for equipment or less inventories for process of certain material for the same throughput.
(d) Less usage of utility material and feedstock for a given throughput and given equipment size.
(e) Higher performance for given unit size.

On the other hand, process integration has been recognized as a useful tool for intensifying processes; see, for example, Lutze et al. [3], El-Halwagi [4], and Gopalakrishnan et al. [5]. Particularly, energy and mass integration have been identified as powerful tools for improving processes. Energy integration allows reducing the energy consumption in industrial processes through intensifying the

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Research Article **Open Access**

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Keywords: Ethanol Anhydrous, Pressure Swing Adsorption, Pressure Equalization

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1 Introduction

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Experimental study of the production of high purity ethanol using a semi-continuous extractive batch dividing wall distillation column

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ABSTRACT

In this paper, the production of high purity ethanol using an experimental dividing wall distillation column using glycerol as entrainer is studied considering batch and semi-continuous operations. In the semi-continuous distillation, an ethanol-water mixture of composition 92% wt. ethanol was introduced in the pot and the glycerol was supplied through a continuous feed near to the top of the distillation column, it was possible to produce a distillate with a composition higher than 99% wt. ethanol. This result is important since it is possible to use this ethanol mixed with gasoline in the current motor vehicles operated with gasoline.

1. Introduction

Despite the process used to obtain bioethanol, a diluted stream of bioethanol is obtained (around 10% wt. of ethanol) and fed to a process separation in order to recover the bioethanol [1]. Several methods have been used to obtain high purity bioethanol, usually a first conventional distillation column is used to remove the water as bottoms product and the distillate contains most of the bioethanol [2]. This first distillation column plays an important role since as the distillate reaches the azeotrope composition of ethanol-water the energy required in the reboiler increases exponentially, thus a negative net energy gain can be obtained in the cycle of production of bioethanol. For that reason, the composition reached in this distillation column is really important as explained in the work of Kiss et al. [1]. In order to obtain high purity bioethanol the preferred industrial method is the extractive distillation using several entrainers; for instance, ethylene glycol, glycerol, ionic liquids and others [3]. From an economic point of view, the glycerol is the cheapest and is obtained as a side product in the production of biodiesel.

This extractive distillation process can be improved by using a dividing wall distillation (DWDC) that can save both energy and capital costs [4]. The DWDC is thermodynamically equivalent to the Petlyuk distillation column when no heat transfer occurs through the wall (Fig. 1). Both complex distillation columns can be used for the separation of a ternary mixture (ABC), where component A is obtained as top product, component B as side stream and component C as bottoms products.

It has been proven the effective use of DWDCs in the purification of bioethanol [5], reactive distillation to produce biodiesel and esterification reactions [6], but most of the studies have been carried out using process simulators, so that the main contribution of this paper is in the experimental production of high purity bioethanol using a DWDC and glycerol as entrainer since the use of ethylene glycol can be forbidden in the near future due to its toxicity [7]. It is important to highlight that in those applications, authors have reported energy savings of around 30% in contrast to the conventional distillation sequences. For that reason, we are interested in using DWDCs in the purification of bioethanol using glycerol, since distillation and dehydration can represent up to 37% of the total energy involved in the cycle of production of bioethanol [2]. Then, the reduction of the energy required in the purification stage is an important opportunity to improve the whole process of production of bioethanol.

2. Details of the experimental DWDC

We have designed, implemented and operated a DWDC that consists of three packed sections of Teflon™ Raschig rings, the sections are numbered from the pot to the condenser (see Fig. 2),

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Financial Risk Assessment and Optimal Planning of Biofuels Supply Chains under Uncertainty

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Abstract Biofuels provide an attractive alternative for satisfying energy demands in a more sustainable way than fossil fuels. To establish a biorefinery, an optimal plan must be implemented for the entire associated supply chain, covering such aspects as selection of feedstocks, location, and capacity of biorefineries, selection of processing technologies, production amounts and transportation flows. In this context, there are several parameters, including the availability of biomass, product demand, and product prices, which are difficult to predict because they might change drastically over the different seasons of the year as well as across years. To address this challenge, this work presents a mathematical programming model for the optimal planning of a distributed system of biorefineries that considers explicitly the uncertainty associated with the supply chain operation as well as the associated risk. The potential of the proposed approach is demonstrated through its application to the production of biofuels in Mexico, considering multiple raw materials and products.

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Introduction

In the recent past, biomass has gained considerable attention as feedstock for the production of several products, especially for energy production through biorefineries [1]. Biofuels can be produced from selected agricultural biomass, proving a sustainable and eco-friendly energy option [2]. The implementation of biorefineries requires the analysis of several aspects, especially the biomass yield on the farm and the fuel production in the biorefinery because these two factors are the most powerful in determining the efficacy of a biofuel production system [3]. Other important factors include feedstock selection, processing routes, products, harvesting sites, processing facilities, and markets, which can be addressed through the optimization of the corresponding supply chain [4]. According to Georgiadis et al. [5], most of the reported approaches for designing supply chains have addressed decisions about the location of new facilities, selection of technologies, feedstocks, products, and distribution of feedstocks and products. In the context of biorefineries, several works on supply chain design have been developed. This way, Van Dyken et al. [6] presented a mixed-integer linear programming model (MILP) for designing biomass-based supply chains. Natarajan et al. [7] developed a model to determine the optimal locations of processing plants for methanol production. Shabani and Sowlati [8] studied the supply chain configuration of a forest biomass power plant. Lin et al. [9] presented a supply chain optimization model to minimize the annual bioethanol production cost, simultaneously considering

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Integrated design and control of multigeneration systems for building complexes

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ABSTRACT

Building complexes have demands of electricity, cooling capacity for air conditioning, and sanitary hot water. These demands can be met efficiently using multigeneration systems. The design of a multigeneration system involves three integrated layers of decisions that include technology selection, equipment sizing and operational (control) policy design. In this work we cast this integrated design problem as a multi-objective mixed-integer nonlinear programming problem. The optimization formulation considers internal combustion engines, fuel cells, microturbines, Stirling engines, solar water heaters, and absorption chillers as technology options. The formulation also considers the sizing of a storage tank for hot water. Optimal operating policies are considered using daily scenarios of ambient temperature, solar radiation, fuel costs, electricity prices, and energy demands over an entire year. We compute compromise solutions that trade-off total annual costs, greenhouse gas emissions, and water consumptions. The method is demonstrated using real data for a Building complex with 420 households located on the Pacific Coast of Mexico. Our approach finds technologies that provide an optimal compromise between cost, emissions, and water consumption. In particular, we have found designs that reduce water consumption by 75% and emissions by 74% compared to the cost minimization case while increasing total cost by only 10%.

1. Introduction

Building complexes present high demands of electricity, heating, and cooling services. These demands can be covered using sustainable generation and storage technologies [1]. Combined Cooling, Heat and Power (CCHP) systems, which are commonly called multigeneration systems [2], are promising technologies to provide multiple utilities for building complexes, and offer several benefits including high utilization efficiencies and the potential to integrate sustainable primary energy sources. Its implementation, compared with conventional thermoelectric plants, reduces fuel consumption [3], and consequently operational costs [4] and greenhouse gas emissions [5]. Also, due to the size, capacity and operational flexibility of the CCHP units, other technologies for alternative energy can be included as auxiliary equipment according with local conditions and available resources [6]. These benefits ultimately lead to reduced environmental impact and can foster deployment of decentralized resources at a system level to increase flexibility [7]. The design and control of multigeneration systems for residential use is complicated by several factors. Building electricity and thermal loads follow different and complex daily patterns that are dictated by social behavior and weather. Consequently, these factors cannot be forecasted and coordinated precisely [8] and play a critical role in choosing appropriate CCHP configurations [9]. Local variations of energy market conditions also affect the selection of CCHP configurations. In particular, the interaction with the local power grid influences operational policies and equipment sizing [10]. CCHP design is also complicated by the need to consider multiple conflicting metrics and the need to account for dynamics of storage units [11].

CCHP design studies reported in the literature focus on different aspects of the problem. Most studies do not fully capture variations of demand, weather and market conditions, and thus might miss extreme conditions and/or correlations. In particular, many studies

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