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Application of optimal design methodologies in retrofitting natural gas combined cycle power plants with CO_2 capture

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HIGHLIGHTS

- A new approach is proposed for retrofitting NGCC power plants with CO2 capture.
- HTI techniques are developed for improving heat recovery in NGCC power plants.
- EGR techniques are developed to increase the process overall energy efficiency.
- The proposed methods are efficient for practical application.

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ABSTRACT

Around 21% of the world's power production is based on natural gas. Energy production is considered to be the significant sources of carbon dioxide (CO_2) emissions. This has a significant effect on the global warming. Improving power plant efficiency and adding a CO_2 capture unit into power plants, have been suggested to be a promising countermeasure against global warming. This paper presents a new insight to the application of energy efficient technologies in retrofitting natural gas combined cycle (NGCC) power plants with CO_2 capture. High fidelity models of a 420 MW NGCC power plant and a CO_2 capture plant with CO_2 compression train have been built and integrated for 90% capture level. These models have been then validated by comparisons with practical operating data and literature results. The novelty of the paper is to propose optimal retrofitting strategies to minimize the efficiency penalty caused by integrating carbon capture units into the power plant, including (1) implementing heat transfer intensification techniques to increase energy saving in the heat recovery steam generator (HRSG) of the power plant; (2) extracting suitable steam from the HRSG to supply the heat required by the capture process, thus on external heat is purchased; (3) employing exhaust gas recirculation (EGR) to increase the overall energy efficiency of the integrated process, which can benefit both power plant (e.g. increasing power plant efficiency) and capture process (e.g. reducing heat demands). Compared with the base case without using any integrating and retrofitting strategies, the optimal solution based on the proposed approaches can provide sufficient heat to CO_2 capture process, and keep the same power generation. The optimal solution shows that, the flue gas flow-rate is reduced 33% in the inlet of CO_2 capture process, heat demand in CO_2 capture decreases 4.3%, heat output from the power plant increases from 0 MW to 133 MW, and more than 22% of profit is obtained in the integrated system. This demonstrates the validity and efficiency of the proposed approaches in retrofitting existing NGCC power plants with CO_2 capture.

1. Introduction

Population growth and technological development in the world, has led to an energy demand that has been increased proportionally. The main sources to produce energy have been power plants, which operate on different types of fuel. However, power plants produce large amounts of greenhouse gas emissions such as carbon dioxide (CO_2), which has a significant effect on the global warming, raising the earth's temperature. Reducing CO_2 emission in power plants has been widely investigated by using combined cycle technologies to improve power plant efficiency and employing carbon capture and storage (CCS) unit to mitigate CO_2.

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