Post-combustion carbon capture for gas turbine : assessment of technical feasibility, performance and flexibility

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As renewable energy sources rapidly expand, they challenge traditional thermal power systems, highlighting the need for adaptable and efficient solutions to maintain grid stability. Gas turbines, recognised for their high efficiency and flexibility, are emerging as crucial players in this transition. However, to truly meet climate goals and reduce carbon footprints, these turbines must integrate advanced carbon capture technologies. In this context, this PhD thesis investigates the potential of retrofitting both small-scale micro Gas Turbines (mGTs) and large-scale Combined Cycle Gas Turbine (CCGT) plants with amine(s)-based post-combustion carbon capture (CC) systems. Through detailed thermodynamic simulations using Aspen Plus and Thermoflex, the study assesses the impact of carbon capture on gas turbine performance and explores strategies to mitigate efficiency penalties.

For micro Gas Turbines used in Combined Heat and Power (CHP) applications, the conventional carbon capture process using monoethanolamine (MEA) leads to a substantial decrease in CHP efficiency from 80% to 60%. By incorporating Exhaust Gas Recirculation (EGR) and testing alternative solvents, such as methyldiethanolamine (MDEA) blended with piperazine (PZ), the research identifies potential improvements but also reveals significant challenges regarding the application of amine(s)-based carbon capture for mGTs. In contrast, applying carbon capture to large-scale CCGT plants demonstrates more promising results. While the direct application of the conventional MEA process to a 60% efficiency CCGT plant initially reduce plant efficiency by 13.5 percentage points, modifications like EGR, heat integration and optimized solvent use can lower the efficiency penalty to 6.2 percentage points. Nonetheless, challenges remain regarding part-load operations, necessitating further advancements for enhanced operational flexibility.

This thesis provides critical insights into the feasibility and performance of carbon capture for gas turbines, setting the stage for future economic assessments and guiding the development of sustainable and low-carbon power generation technologies.

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