Demonstration of EMPC of a Solvent-based Carbon Capture Pilot Plant

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Abstract: To limit global warming, carbon capture, utilization and storage plays an important role. Solvent-based post-combustion carbon capture is a mature technology for capturing CO_2 from flue gases, but high operational costs, primarily due to the energy-intensive solvent regeneration process, hinder large-scale deployment. To reduce the operational costs, model-based advanced process control (APC) plays a key role, by enabling dynamic and flexible operation. APC can take advantage of fluctuating energy prices by shifting the energy demand to periods with low prices while ensuring that minimum requirements for the CO_2 capture rate are met. In this study, we develop, implement and demonstrate an economic model predictive controller (EMPC) of a solvent-based carbon capture pilot plant, located at the Danish Technological Institute (DTI). Using a data-driven neural network-based grey-box model of the pilot plant, we formulate 1) an optimal control problem (OCP) which minimizes the energy consumption (i.e. no price-sensitivity) and 2) an OCP which minimizes the operational costs, assuming time-varying energy prices. We assume a sinusoidal energy price with low prices in the first half and high prices in the second half of the 6h test period. Additionally, both OCPs have a minimum CO_2 capture rate requirement. We implement and test the controllers in both open-loop (without system feedback) and closed-loop (with system feedback). Figure 1 shows resulting key performance indicators (KPIs) during all tests and Figure 2 shows the final KPIs at the end of each test. The results demonstrate that the closed-loop EMPC both satisfies the total CO_2 capture rate requirement (30% capture) and reduces the operational costs by shifting the energy demand to periods with lower energy prices. With the chosen energy price profile, the closed-loop EMPC achieves a cost reduction of 26%, compared to the price-insensitive closed-loop controller which only minimizes the energy consumption. This study demonstrates the potential of EMPC for solvent-based carbon capture and shows how dynamic and flexible operation can lower the operational costs of complex industrial processes.

Keywords: Solvent-based carbon capture, economic model predictive control, flexible operation, optimization, data-driven modeling

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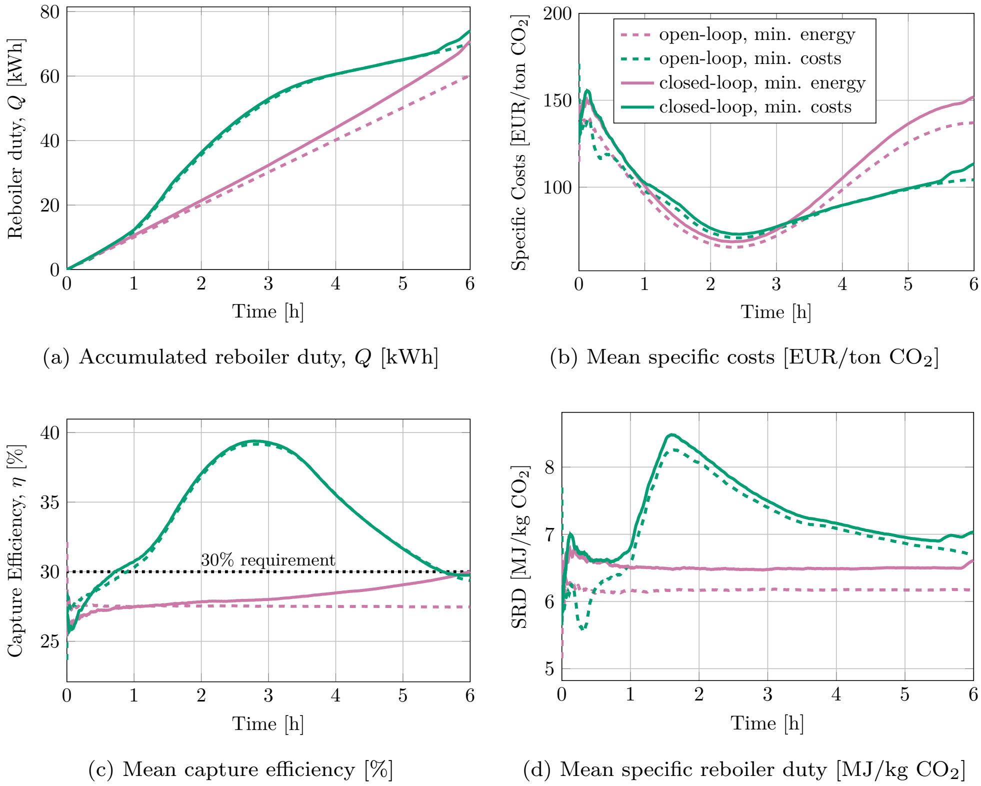

(a) Accumulated reboiler duty, Q [kWh]

(b) Mean specific costs [EUR/ton CO_2]

(c) Mean capture efficiency [%]

(d) Mean specific reboiler duty [MJ/kg CO_2]

Fig. 1. KPIs during the open-loop and closed-loop tests.

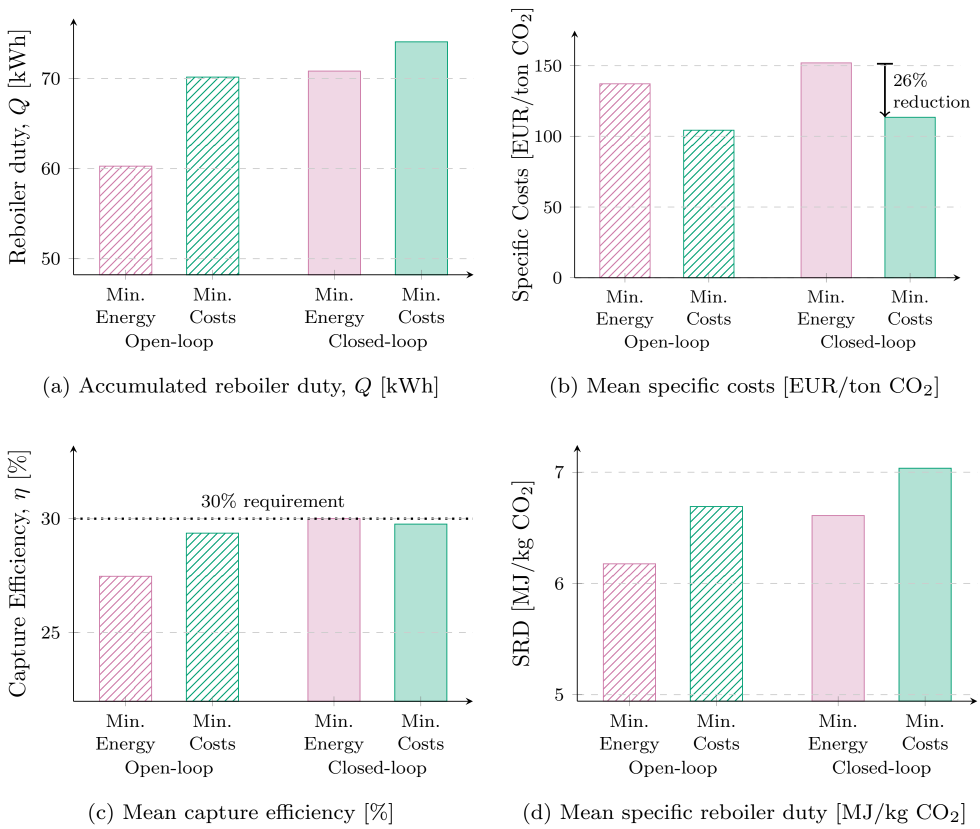

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Fig. 2. Final KPIs at the end of the open-loop and closed-loop tests.