DECARBONISATION OF DISTILLATION USING MECHANICAL VAPOR RECOMPRESSION (MVR)

Akash S..[1], Ruiz Zamarro L.C[2], Crespo Machon E.[2], Schultheiß J.[3], Grau Tena M.[4], Alakivimaki S.[5]

[1] University of Padua, Italy; [2] University of Valladolid, Spain;

[3] Kaiserslautern University of Applied Sciences, Kaiserslautern, Germany;

[4] Polytechnic University of Catalonia, Spain; [5] Turku University of Applied Sciences, Finland;

Abstract

Distillation is one of the most energy-intensive unit operations in the chemical process industry, accounting for a substantial share of global industrial energy consumption and associated CO_2 emissions. This study investigates the operational cost (OPEX) and carbon footprint of separating an 18,000 kg/h water–ethanol mixture using two configurations: a conventional steam-heated distillation column and one equipped with Mechanical Vapour Recompression (MVR). Process simulations were carried out using Aspen Plus with the NRTL thermodynamic model for a 30-stage atmospheric distillation column producing >90 wt.-% ethanol distillate. The conventional configuration was evaluated using 5-bar steam as the heat source, while the MVR configuration utilises a compressor to upgrade the overhead vapour and recycle it as the reboiler heat source, eliminating or significantly reducing steam consumption. OPEX calculations incorporate utility costs (steam, electricity, cooling water) and CO_2 certificate costs at 60 €/t. Key performance indicators, including the Coefficient of Performance (COP), Carnot COP, and second-law efficiency, were computed to benchmark the thermodynamic quality of the MVR system. Results demonstrate that MVR significantly reduces total OPEX by substituting electrical work for thermal energy input, with the magnitude of savings depending on the electricity source (grid mix vs. renewable). This study highlights MVR as a viable electrification strategy for industrial distillation, contributing to broader decarbonisation goals in process engineering.

Keywords: Mechanical Vapor Recompression; Distillation; Decarbonisation; Aspen Plus; COP; Electrification