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Industry 4.0 Enabled PILOT Facility in DTU Chemical Engineering

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Topics in digitalisation and industry 4.0 have become the centre point of a new frontier in the chemical and biochemical manufacturing industry over the last decade. Especially the area of Digital Twins (DT) is diligently being explored by industry and academia to improve large-scale operational efficiency and -characterisation through tighter data integration between the physical system and digital entities [1, 2]. The implementation of DT in the biochemical- and pharmaceutical industry is severely restricted by the low degree of automation in typical production lines and the complexity of the digital models used in predictive toolboxes [2, 3]. Most publications demonstrating digital twin implementations in biomanufacturing processes are often limited to laboratory-scale setups and automated case studies. There is a significant lack in the literature that explores how to employ tight data integration for improving operations at a larger scale with operators responsible for key decision-making.

To address this demand, the Department of Chemical and Biochemical Engineering at DTU initiated a comprehensive retrofitting and expansion initiative of the existing pilot plant laboratory in 2021 to enable the research and development of digital twins for common large-scale process operations [3]. Since 2021 key infrastructure has been commissioned that achieves easy, tight, and flexible integration between digital and physical entities. The implemented digital infrastructure achieves a flexible operation through a two-layer approach. The first layer consists of augmenting each unit with access to a proprietary IoT gateway software (vNode) which allows for the modular addition of sensors. The second layer is the incorporation of a cloud server infrastructure that can easily be scaled based on computational demand.

This work presents an overview of the completed commissioning of pilot plant 4.0 and a workflow that enables large-scale integration and development of digital twins for unit characterisation and operator support using a simple batch distillation column as an example. The batch distillation column includes a range of online and offline sensors combined with at-line measurements performed by the operator. The reflux ratio and the product flow are controlled by a set of manual valves that the operator must balance to achieve a steady operation. Poor control of the valves will lead to a very oscillating operation that may result in a violation of product composition and complete draining of the condenser.

[1] Bähner F., et al., 2022, Challenges in Optimisation and Control of Biobased Process Systems: An Industrial-Academic Perspective, Industrial and Engineering Chemistry Research, vol 60, issue 42, 14985-15003

[2] Cimino C. et al., 2019, "Review of digital twin applications in manufacturing", Computers in Industry, vol 113

[3] Jones M., et al., 2022, Pilot Plant 4.0: A Review of Digitalization Efforts of the Chemical and Biochemical Engineering Department at the Technical University of Denmark (DTU), Computer Aided Chemical Engineering, vol 49, 1525-1530

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