Non-linear Modelling and PID Control for CO_2 Pipeline-Injection Networks

Archana Kumaraswamy [*] **Johannes Jäschke** [*]
Audun Faanes [**,***]

[*] *Department of Chemical Engineering, Norwegian University of Science and Technology (NTNU), Trondheim, Norway*
[**] *Equinor ASA*
[***] *Department of Geoscience, Norwegian University of Science and Technology (NTNU), Trondheim, Norway*

Abstract: Control strategies for carbon dioxide (CO_2) transport and injection systems remain largely unexplored in the literature. Driven by the urgent need for decarbonization and the geographical separation between CO_2 emission sources and storage sites, integrated CO_2 transport and injection networks are actively being developed worldwide (East Coast Cluster, 2025; Northern Lights, 2025). Key operational challenges include minimizing energy consumption while maintaining stable operation under disturbances such as fluctuations in upstream CO_2 capture rates (Spitz et al., 2018) and changes in well injectivity. To ensure efficient and reliable network performance, a control system must satisfy key operational objectives, such as accurate wellhead injection flow tracking and the enforcement of pressure constraints. This study investigates a pipeline-injection network structure inspired by Ruud (2024), where a main CO_2 export line transports CO_2 offshore for sequestration as shown in Figure 1. A PID control structure is implemented and evaluated within a dynamic simulation framework. Two candidate modelling environments are considered: a Ledaflow multiphase flow simulator and a simplified first principles dynamic model. PID control is investigated as it provides effective regulation of key operational parameters at low computational cost, and naturally lends itself to integration within hierarchical control frameworks where model predictive control (MPC) and real-time optimization (RTO) operate at higher levels.

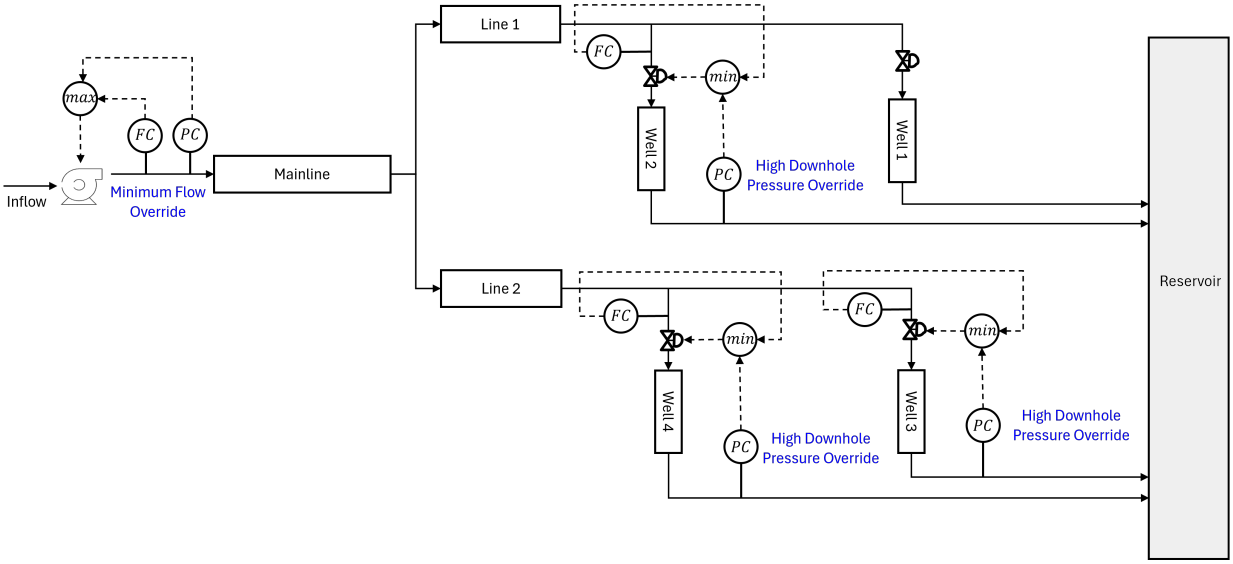

Fig. 1. CO_2 pipeline-injection network modelled in this study

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