# Demonstration of two-level non-linear model predictive control of $CO_2$ capture plants

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Abstract

During the course of the national project DOCPCC which was finalised end of December 2017, an advanced control system based on nonlinear model predictive control (NMPC) was successfully demonstrated at both the Tiller and the TCM test facilities. NMPC provides multivariable control actions by repetitive dynamic optimization of the future predicted responses, resulting from a dynamic model of the plant. At both the Tiller and the TCM test facilities the energy input to the reboiler and solvent flow-rate were manipulated simultaneously such that the Specific Reboiler duty (SRD) was minimized while the capture rate was kept at a specific level during changing operating conditions (e.g. change in flue gas flow-rate and change in flue gas $CO_2$ concentration). The prediction horizon for the control action was 5 hours. Compared to manual operation it was seen that the NMPC controls both tighter and faster and that the SRD is kept more constant. Some preliminary results were presented at the PCCC-4 conference ([1]) and in Figure 1 some results from one test at the TCM facility is shown. Though it can be concluded that the major purpose of using such advanced control system in test facilities is to ensure efficient control actions thereby reducing the time from one steady state to another is reached after changing operating conditions, the most important gain in larger scale capture plant will be energy reduction as well as reduction in the operational man-hours.

Large-scale design and operation was discussed extensively in the EU funded project OCTAVIUS (e.g. [2]) and more specifically two important operational issues were addressed. These issues are related to control of the capture plant and flexible operation. Regarding the latter flexible operation related to using intermittent stripping was tested at the Brindisi pilot plant owned and operated by ENEL. Based on a dynamic process model of this pilot plant also other operating modes were simulated and evaluated ([3]). This work was motivated by how a capture plant may be operated in a load following manner if the upstream power-plant is operated in a variating electricity demand and price marked regime. However, it must be emphasized that a changing electricity price will be important for any application of absorption based capture plants and as such this motivates for a two-level optimization approach for the NMPC application.

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Within an extension of the DOCPCC project, the goal is to demonstrate at both Tiller and the TCM test facilities the action of the basic level NMPC control function, which is again controlled with an upper level optimization routine. While the basic level will have the same 5 hours prediction horizon, the upper level will have a much longer prediction horizon (24 hours or even longer) and will optimize the capture rate under varying power prices. That is; the total power cost will be minimized over the horizon subject to the constraint that the average capture rate over the horizon is at least 90%.

A challenge with the two-level optimization is related to the real-time requirements for computational efficiency. The dynamic process model has been optimized for the application in that respect, but applied at both levels, the simulation time is too long and further simplification is necessary. However, since the prediction horizon for the upper level is much longer than the basic level, the parts of the model contributing to the slower dynamics will be more important than the parts contributing mostly to the fast dynamics. With this in mind the dynamic model used in the NMPC application at the upper level will be simplified. A demonstration at both the TCM and Tiller facilities will be conducted during the spring of 2018 and the results will be presented at the conference. At the Tiller facility, the NMPC control action will be demonstrated also with intermittent stripping by utilizing intermediate solvent storage tanks.

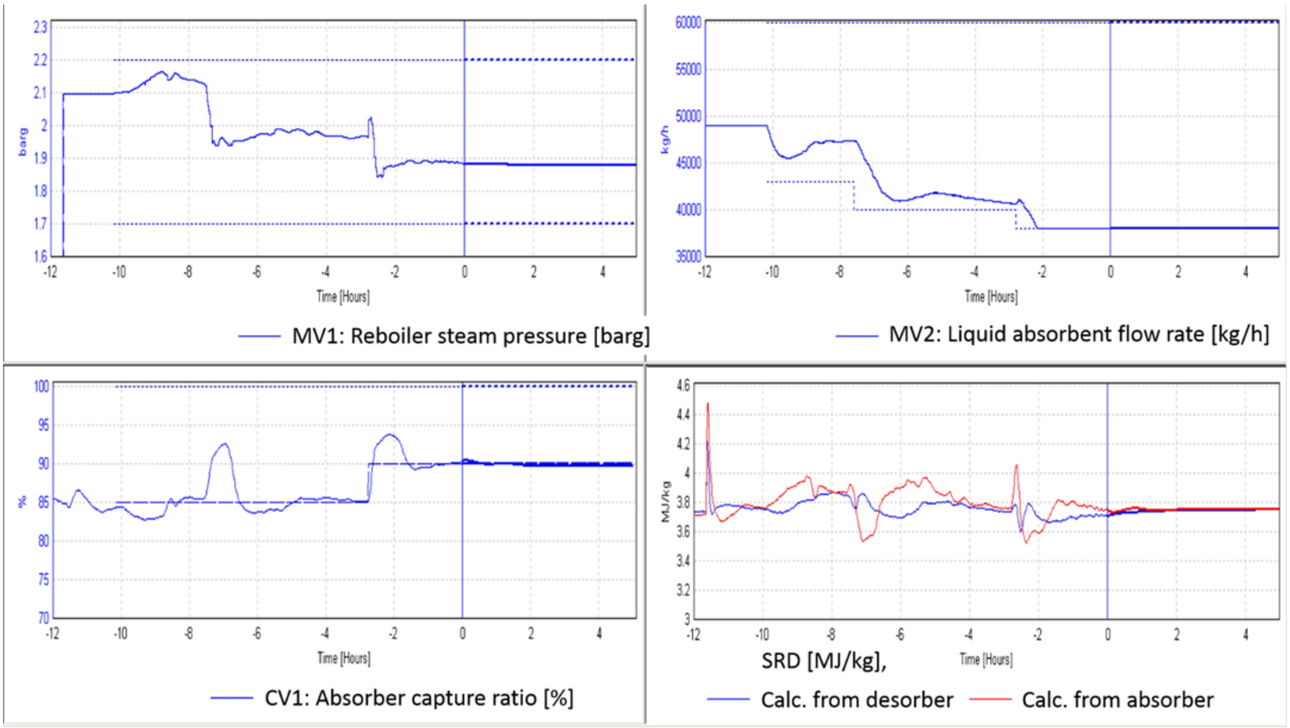


Figure 1: Controller test TCM – changes in flue gas flow rate. Lines to the left of the vertical line marking time 0 means history, while the predictions from CENIT are shown to the right. The reboiler steam pressure input is given in barg (upper left graph). The mass flow of lean amine is given in kg/hours (upper right graph), the set-point changes (dashed line) and the resulting response (solid line) in capture rate is given in % (lower left graph), and the SRD is given in MJ/kg $CO_2$ captured (lower right graph).

**References:**

[1] Kvamsdal, H.M., (2017), Testing of advanced control system at the Tiller and TCM pilots, presentation at the PCCC-4 conference, Birmingham, Alabama, USA, 6.-7. September

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