Machine Learning in the NAPCON Advisor

Overview

Starting in May 2018, NAPCON and Curious AI have cooperated in the development of an artificial intelligence-based application for the process industry, to assist in the safe, economic operation of industrial process plants. This application is aptly named the NAPCON Advisor.

The application has now been tested successfully with a high-fidelity NAPCON Simulator process model and real process plant data, showing that it both accurately predicts long term process outcomes, and generates optimal control action suggestions for improving the process outcome. Following these successful trials, taking the technology into production use is now underway.

This white paper describes results of testing the technology, specifically the machine learning based model.

Background

For years the preferred method in the process industry has been for operators to train "on the job" to familiarise themselves with the dynamics of a production plant. However, to reach a point where an operator can function independently takes years. This poses a need for better operator training facilities, and better automation assisting the operators in the field.

NAPCON and Curious AI are now using state-of-the-art machine learning technology to provide a method for advanced operator training, real time insights to day to day operations, and for automatically generating optimal control actions safely and accurately.

Benefit of using a machine learning based model is that the simulation can be created without any engineering work, which first principles models require. This makes it possible to accurately model in principle any process, which may have been too non-linear, complex or unique to model before.

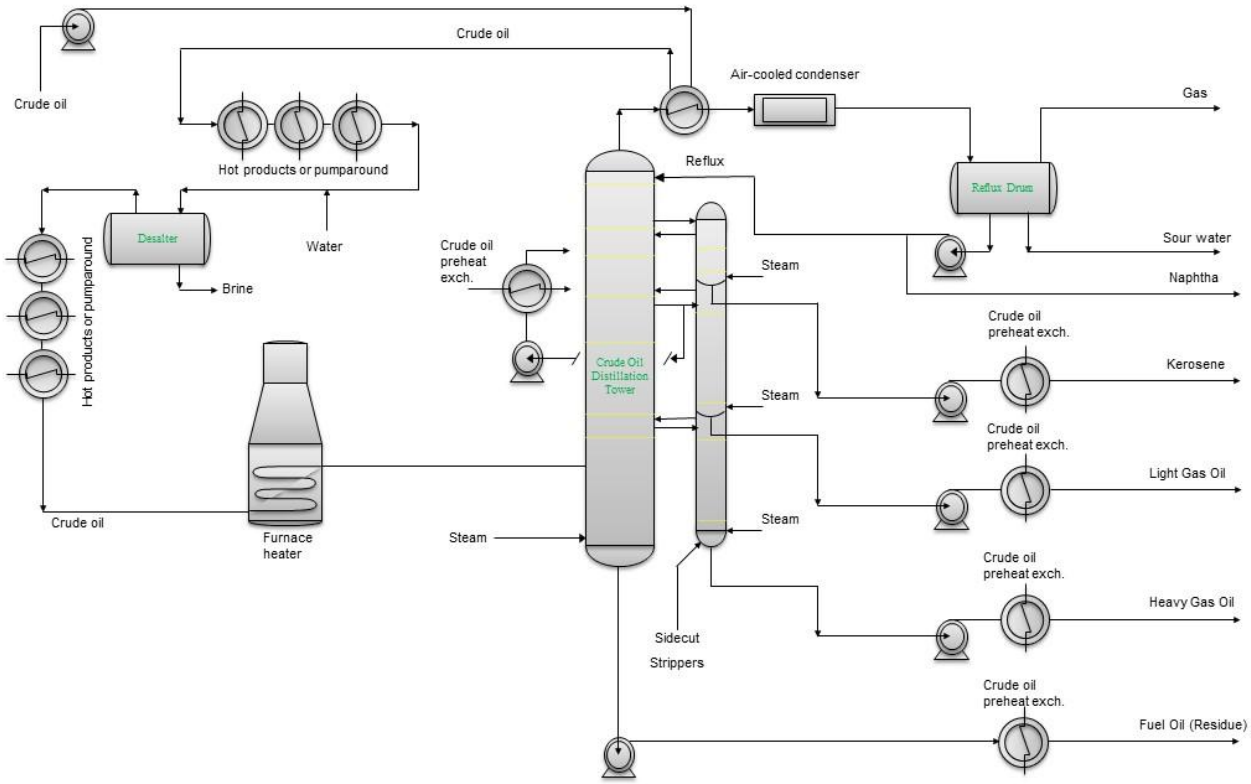

Figure 1: Process diagram of a typical northern European crude distillation unit (CDU).

NAPCON Process Simulation tests

A simulated Northern European Crude Distillation Unit (CDU) was used as a test target. The process was chosen for its demonstrative qualities and rich, challenging dynamics, while also being sufficiently well known to avoid data or process confidentiality issues. The demonstration tasks were:

1. Real time prediction of the main column performance 20 hours into the future
2. The generation of an optimal operator control action plan for a production mode change.

The control task comprised 180 measured variables and 6 control variables (setpoints). The model output was a prediction of all measured variables 20h into the future, as a time series with 30s time resolution. Accurately predicting the process state at every point in time, even during transitions, is important for providing the operator with insight into the process dynamics, and for being able to optimise profit over the transitions.

A total of 180 days of simulated process data, with added disturbances such as feed composition changes, was produced for testing and training the model. For training the prediction model, few weeks of data was enough. The AI system interfaced with the simulator through the existing OPC UA interface, for future compatibility with real process plants.

For evaluation, NAPCON provided an operator reference scenario, where an experienced human operator executed a winter to summer to winter light gas oil (LGO) quality change. The evaluation task was to predict the process state at every time during the scenario, and to optimise profit over the transitions.

Real-world plant data tests

A corresponding, proprietary real plant process was also tested against the prediction model. Data collected from the real-world process was used to train and test the model, to ensure that the model works not only with the simulated data, but actual process data as well.

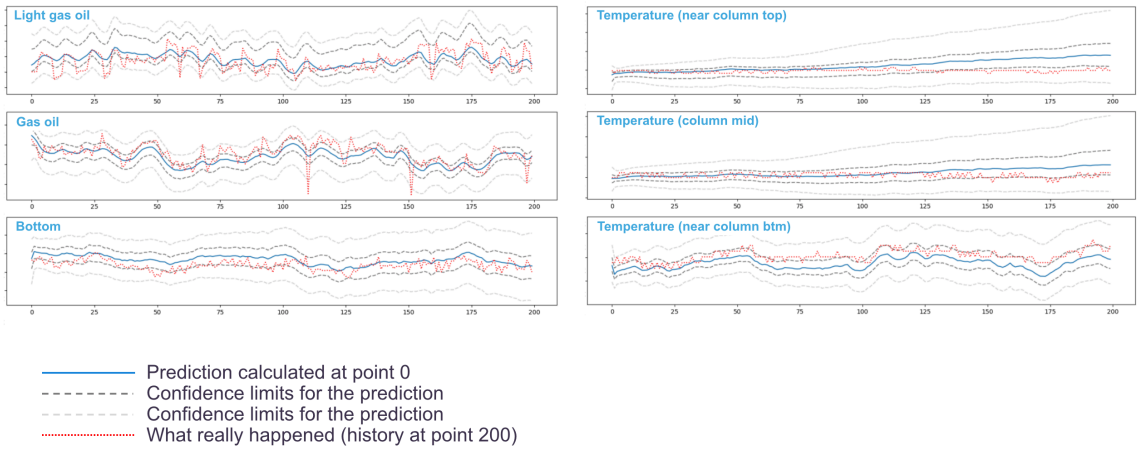

Figure 2: Model prediction of the real plant process, and the actual realised outcome. measurement scales have been omitted from the graphs for data confidentiality reasons.

Process prediction results

Testing showed that the model correctly predicts the process variables 20 hours ahead, both with the simulated process, and a real-world plant data. Figure 2 shows the model predictions of some of the real plant measurements, overlaid on top of the realised values over the following 20h. The prediction can be seen to match the realised process state, and where there is deviation, the model confidence intervals correctly indicated this at prediction time.

Process control results

Operator action suggestions are created by taking the neural prediction model and optimising the planned actions against the profit function. The most essential part of the optimisation is the proprietary neural network training regularisation developed by Curious AI, a part of their Neural MPC suite. The role of the regulariser is to:

1. Make action suggestions safe
2. Make action suggestions human-like so that the solution is understandable
3. Mediate expert operators' tacit knowledge to less experienced ones
4. Limit suggestions to those that are easy to execute by the operator

The profit function embodies soft and hard limits for the process, raw material costs and product profit. In this task, the profit function included a total of 236 constraints for the optimisation.

Suggested control actions were generated for all 6 setpoints for the next 24 hours. A sharp transition from LGO A to LGO B quality at approximately 9h from the start of the optimisation, and then back from LGO B to LGO A at 16h, was formulated as the objective. Emphasis was put on a smooth and safe transition, thereby encouraging human-like control. In this way the regulariser aims to make the suggested actions more feasible for an operator to implement in practice.

Figure 4 shows the action plan generated by the model. The action plan was tested by executing the suggested actions on the high-fidelity NAPCON CDU simulation, for comparison with the reference operator scenario. The model was able to execute the complicated production mode change, making the test a success. Furthermore, as can be seen in Figure 3, the model very accurately predicted the profit which the action plan would produce, and the realised profit was actually greater than achieved in the human operator reference run. The extra profit resulted from the model finding a plan that ramps the profit back up quicker after the transition, spending less time producing out of spec product.

The model-generated action plan can be reviewed and studied, as it is generated in the form of a time series for each control variable. The plan in Figure 4 can be seen to consist of i) decreasing the LGO draw, affecting the whole distillation curve of LGO, ii) decreasing the stripping steam to the LGO stripper and iii) increasing the HGO draw, all of which seem realistic and reasonable actions, and would work in a CDU unit to the effect of making the LGO lighter.

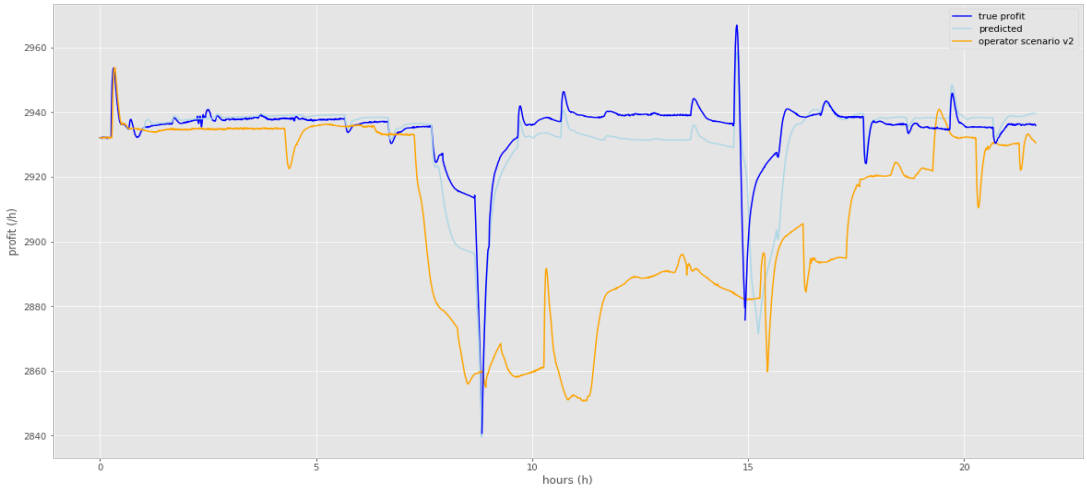

Figure 3: Comparing suggested control action true profit, operator scenario true profit and predicted profit.

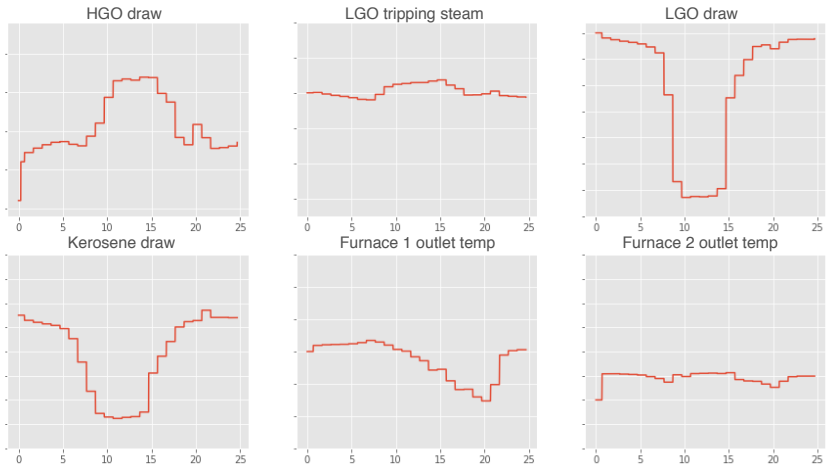

Figure 4: Suggested control actions generated by the NAPCON Advisor model.

Conclusion and discussion

The tests show that the machine-learning based NAPCON Advisor accurately predicts long term process outcomes and the effects of operator actions. It provides optimal new actions for improving the process economics subject to realistic process dynamics and constraints.

The goal of the NAPCON Advisor is to help to run entire processes optimally. In steady operation, it brings safety, stability, economy, maximisation of operating marginal, production, recovery rates and energy efficiency. During transients and disturbances, the NAPCON Advisor helps to return to steady operation, exploit new capacity, and minimise off-spec production.

Process operator work has gone through a major change during the past decades. The ageing workforce landscape, combined with a need for more cost-effective training solutions, are additional challenges in acquiring well-trained operators to take over from retiring ones. Adaptive AI operator co-workers, such as the NAPCON Advisor, and training simulators with accurate models capable of providing more insight into the controlled processes are key to bringing the new generation of operators on board.

Contact

For more information on NAPCON Advisor and related process automation and training simulator software solutions, see www.napconsuite.com.

For more information on practical, industrial and enterprise ready, next-level machine learning and AI software solutions, see www.cai.fi.