CoPro: Optimisation of the operation of heat exchangers

Project:
Improved energy and resource efficiency by better coordination of production in the process industries

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The goal of the CoPro project was to develop and to demonstrate methods and tools for process monitoring and optimal dynamic planning, scheduling and control of plants, industrial sites and clusters under dynamic market conditions, to provide decision support to operators and managers and to progress to automated closed-loop solutions to achieve an optimally energy and resource efficient production.

CoPro brought together 17 partners from 8 EU countries, including 5 industrial end users and 6 technology providing SMEs. The project developed solutions for the **plant-wide optimisation of large plants, for balancing production and consumption in industrial parks for industrial symbiosis**, and addressed **power plant scheduling** and **demand-side response**. It further developed online data analytics for **anomaly detection**, and **decision support** for plant operators and managers. The solutions can be integrated into the IT infrastructure of the plants via an **integration platform** that supports the connection to different IT systems. CoPro developed **model libraries**

for the efficient development of advanced optimisation-based solutions and techniques and software for **hybrid modelling** and **model management**.

The developments of CoPro were motivated by and applied to challenging use cases from different sectors of the process industries:

- (Petro-)chemical production;
- Cellulose fiber production;
- Production, formulation and packaging of consumer goods;
- Sterilisation and packaging of food.

CoPro demonstrated that significant savings of energy and resources are possible by using advanced technologies for monitoring, decision support, optimisation, and planning and scheduling.

Sector:

Chemicals

Water

Summary:

The Problem

- Heat exchangers are crucial elements for the reduction of the energy demand of the processing industry.
- Heat exchangers often suffer from fouling, which decreases the heat transfer and thus the

efficiency of the process.
- Cleaning is needed to recover nominal efficiencies.
- The optimal time for cleaning depends on the usage of the heat exchangers. Overall, these are many operation decisions difficult to take for the plant personnel.

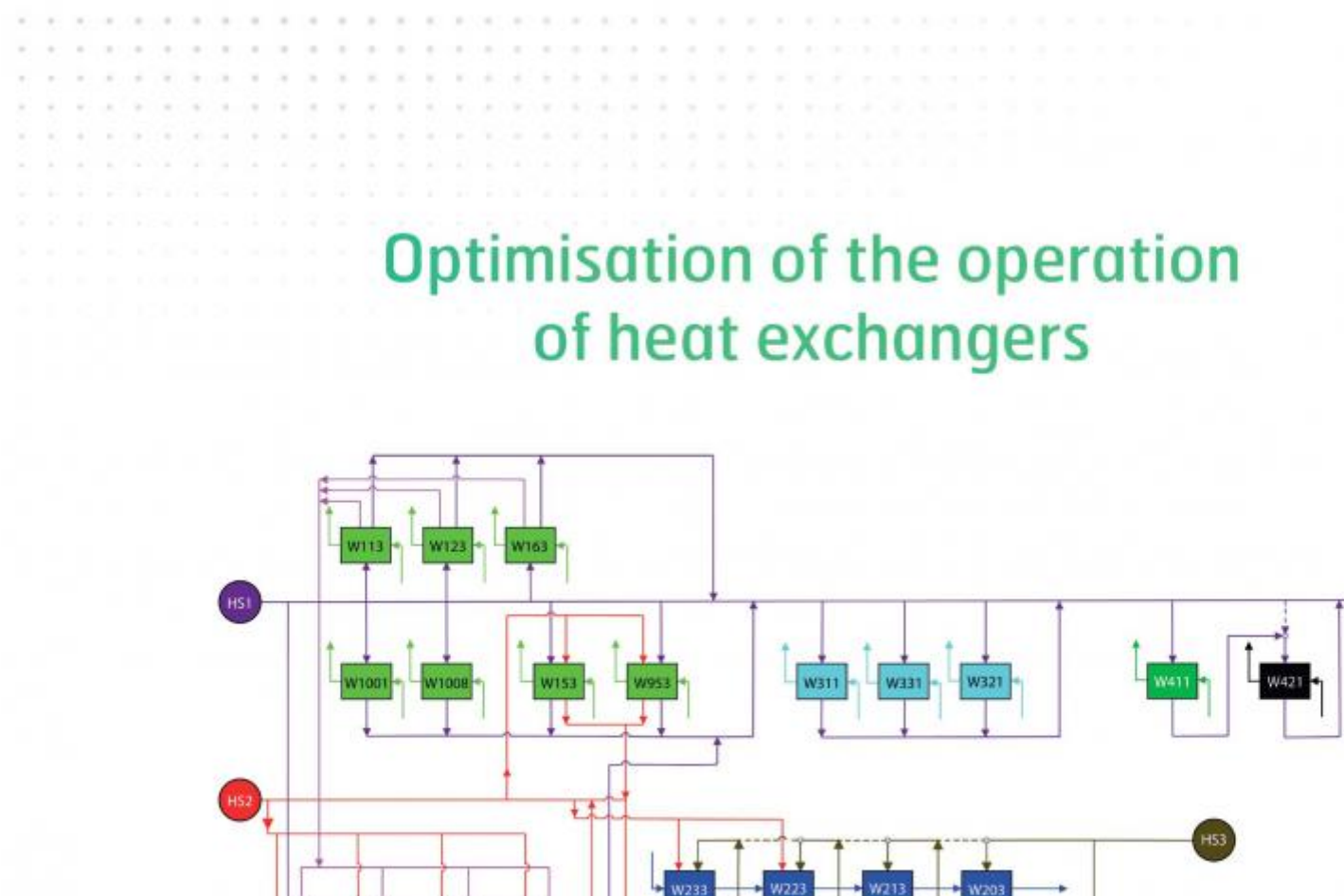
The Solution

- A methodology for monitoring the fouling of their heat exchangers was developed by Lenzing AG.
- Hybrid models for the heat transfer, the evolution of fouling and for the heat-recovery network layout in Lenzing were developed by UVa.
- Model-based real-time optimisation (RTO) tools were developed to support the operators in such complex decision problems.
- The developed decision-support systems enable a quick reaction to disturbances or load changes.

Theme:
Plant-wide monitoring - SPIRE02-2016
Keywords:
Optimal cleaning; Prescriptive maintenance; Network management; Real-time optimisation; Hybrid model; Decision support systems; Online fouling monitoring; Heat recovery; Heat exchangers network; Cleaning schedule; Food; Pulp and Paper
Type:
Case study
Software

Resources

Link:
Technology Short Description: Optimisation of the operation of heat exchangers



Optimisation of the operation of heat exchangers

The problem

Operation policy impacts heat transfer

Heat exchangers play a key role in the evaporation and heat-recovery sections at the Lenzing AG site, in Austria, as in many other plants. Their overall heat-transfer coefficient directly affects the steam consumption, which represents about the 60% of the energy consumption for steam and hot water production in a viscose fiber plant.

In Lenzing, **the operation of heat exchangers must be adapted to the daily production circumstances.** It is well known that the stream flows and temperature differences affect the heat transfer in a heat exchanger (HE). Different control decisions regarding these variables can lead to fulfilment of the production demands, but also lead to different energy demands. In addition, the existence of multiple heat sources with different characteristics, redundant equipment, as well as some degrees of freedom in the layout create a complex decision problem for the plant operators, who are happy to find feasible solutions in many cases.

Furthermore, the **progressive fouling appearing on the heat exchanger surfaces** due to deposition of organic material worsens the situation, requiring a production-maintenance schedule to keep the resource consumption within reasonable bounds. This issue further increases the complexity of the task of the operators.

The solution

A real-time optimisation approach

The solution proposed within CoPro to approach the above problems is a decision support system (DSS) the core of which are **model-based real-time optimisation** (RTO) tools. These tools were developed in cooperation of Lenzing AG and the University of Valladolid. The tools are designed to support plant personnel in the complex task of scheduling the operation and maintenance tasks of the HEs, with the aim of improving the overall resource efficiency.

The DSS consists of two tools: Heat-recovery operation and prediction of optimal cleaning times.

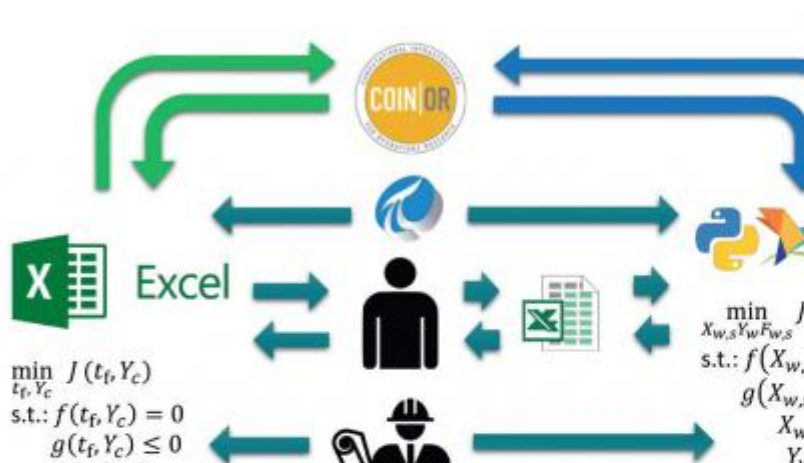


Fig. 1: Information flow of the prototypical DSS

The RTO for the heat-recovery section reads the current state of the HE network from the PI system (including the HEs fouling state that is provided by the developed monitoring system) and decides on the best connection and flows of heat sources to the HEs which fulfils the temperature setpoints. Moreover, it also provides suggestions on which HEs should be cleaned based on the proposed operation and the current state of fouling. In the backend the tool solves a mixed-integer nonlinear programming problem, coded in Python-PYOMO, in less than 5 minutes. The core of the tool is a mathematical model of the reconfigurable network layout and the equations for the heat-transfer physics, including data-based models for the overall heat-transfer coefficient in the HEs depending on their operating conditions.

The cleaning-times prediction tool is implemented in MS Excel to cope with the preferences of the plant personnel, and it serves to predict the best future cleaning instants as well as the type of cleaning for each heat exchanger. The proposal is based on the current and past operation of an HE since its last cleaning. The tool reads operation data from the plant historian and uses the heat-transfer equations and the data-based model for predicting the fouling to compute the operation costs over the time. Then, a computationally cheap (mixed-integer) nonlinear optimisation is solved to find the best trade-off between operation and cleaning costs.

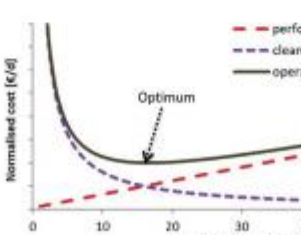


Fig. 2: Economic trade-off in HEs

The two modules were built of each other in order to pro to be reused/replaced in oth heat exchanger networks bu layouts or purposes.

The summary

Improved efficiency heat exchangers

With the proposed approach operation of heat exchanger and the two prototypical too developed, we aimed to mak for the plant operators who difficulties in managing such factors and decision variable The initial tests showed pron in both coordination worklo savings. The application sho of applying hybrid modelling optimisation tools at industr

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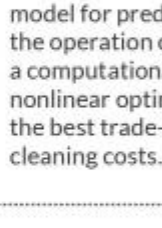

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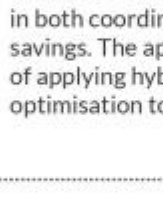

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