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GAS PROCESSING DEVELOPMENTS

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# Override control of fuel gas

When natural gas was to be added to a refinery's fuel gas system, detailed dynamic simulation of the new system ensured stable operation and a shorter start-up period

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**M**iRO oil refinery in Germany has expanded its fuel gas system using natural gas as an additional energy source. The new natural gas system, which includes a complex override control structure, had to be integrated in the historically evolved fuel gas system outside of a shutdown. Therefore, a detailed dynamic simulation study (DSS) of the new and integrated overall fuel gas system was carried out using UniSim Design. The objectives of the DSS include ensuring stable and safe operation of the new system as well as shortening the start-up time.

This article gives an overview of the project and shows initial results after successful start-up of the new fuel gas system.

## Refinery and natural gas import project

MiRO (Mineraloelraffinerie Oberrhein) is one of the largest oil refineries in Germany. The refinery is located in Karlsruhe and consists of two sites which are interconnected in multiple ways (feeds, products and utilities). In the past, the fuel gas system of the refinery was based on liquefied petroleum gas (LPG) and fuel oil as the external make-up energy source. Price changes have made natural gas financially attractive as an additional energy source, and thus MiRO decided to include natural gas as an alternative make-up gas.

A simplified structure of the new integrated fuel gas system with the energy sources – refinery off-gas, FCC gas, coker gas, LPG and natural gas – is shown in **Figure 1**.

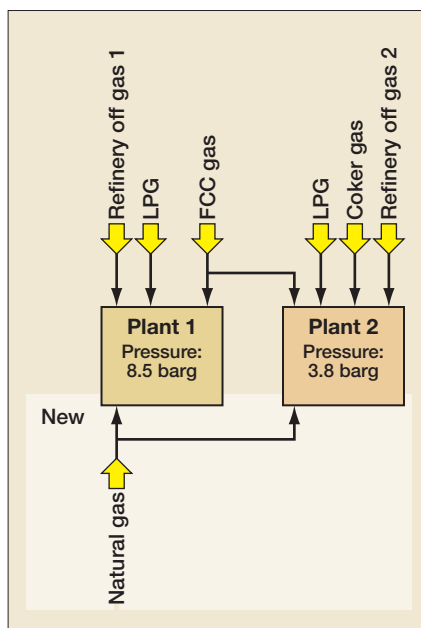


Figure 1 Structure of MiRO fuel gas system (simplified)

In order to meet the varying requirements of the refinery, MiRO has developed a complex override control structure. In addition, piping and control of the new natu-

## Price changes have made natural gas financially attractive as an additional energy source

ral gas system had to be integrated in the historically evolved fuel gas system outside of a shutdown. Therefore a dynamic simulation study of the overall fuel gas system was carried out with the following main objectives:

- Ensuring the integrated fuel gas system is stable in all operating conditions and transition phases
- Ensuring there are no oscillations or other dynamic problems
- Testing the control configuration and pre-tuning the controllers prior to installation
- Ensuring additional control objectives (min/max flow rates, and so on) are met
- Testing that transitions from LPG to natural gas and back, as primary fuel, are easy to handle
- Safe commissioning
- Reducing commissioning time.

## Dynamic simulation of fuel gas system

Dynamic Process Simulators such as Honeywell UniSim Design, Invensys Dynsim, or AspenTech Aspen Hysys Dynamics are based on first principle process modelling engines that allow realistic modelling of the transient behaviour of processes typically found in the oil, gas and chemical industries. In order to create a process model, the user selects readily available components and thermodynamic packages to define physical properties and phase equilibria for the system and then creates a flow-sheet by adding and linking generic unit operation models (pipes, vessels, pumps, distillation columns, for instance) and control equipment (valves, PIDs, and so on). The resulting model can be initialised to a specific initial condition and run through different predefined scenarios as part of a dynamic simulation study.

Dynamic simulation studies are a standard tool in the process indus-

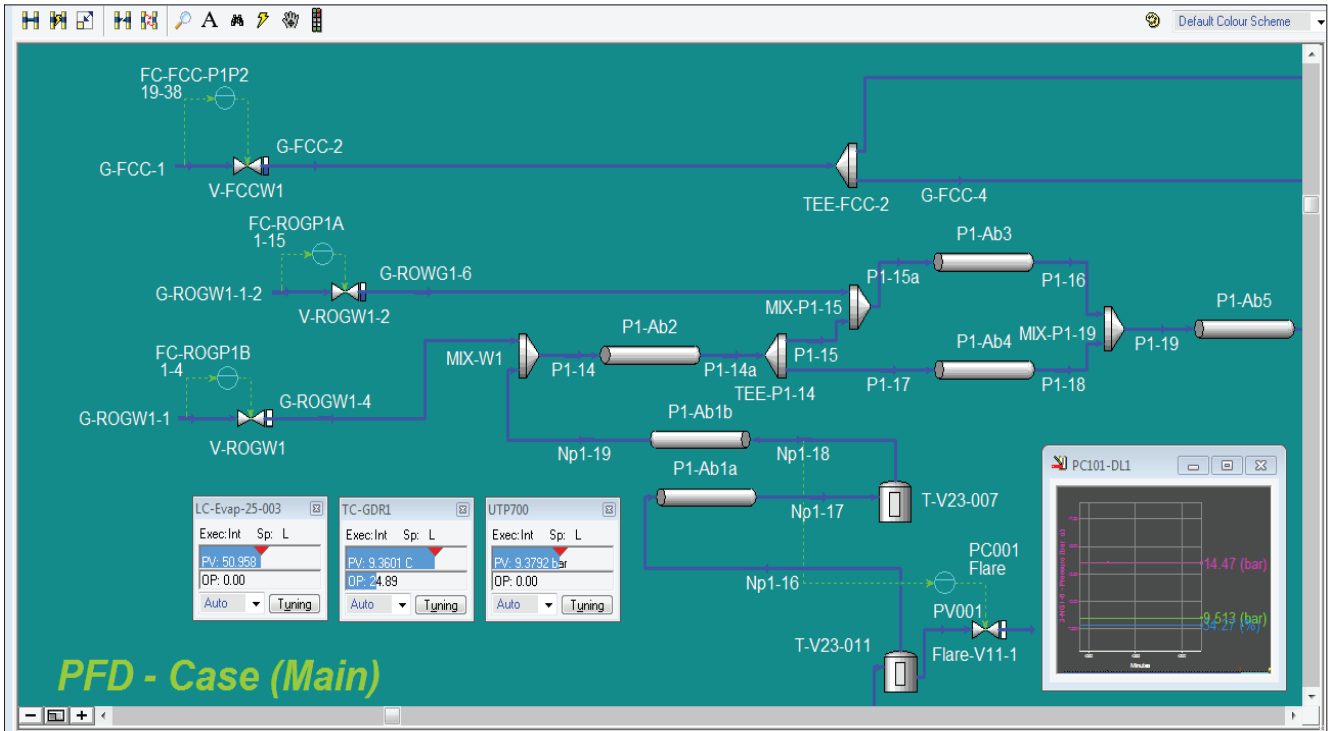


Figure 2 Small section of the UniSim model

tries for analysing and optimising transient process behaviour. Application examples for operability or safety studies include dynamic flare load estimation in refineries<sup>1</sup> or onshore gas fields,<sup>2</sup> and compressor studies.<sup>3</sup> For the DSS carried out at MiRO refinery, the authors selected UniSim Design for its modelling speed, stability and its capability to model complex control systems.

The new natural gas system had to be integrated into the fuel gas system using existing piping and vessels as it was not possible to add new equipment outside of a shutdown (as explained above). This existing equipment is not optimised with respect to capacity and pressure drop, and could lead to problems in the transient behaviour of the integrated system. Figure 2 shows a small section of the overall UniSim model, where piping of the real plant is modelled with great accuracy.

**Override control**

Override control is a control strategy where one manipulated variable is adjusted by two or more controlled variables.<sup>4</sup> Override control typically uses a PI/PID algorithm for each controlled varia-

ble. A low or high selector (LS or HS) chooses between the PI/PID outputs at a given time. Integral parts of the PI/PID controllers

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which are not selected are at risk of integral windup, therefore an anti-windup strategy is required. One option is external reset feed-

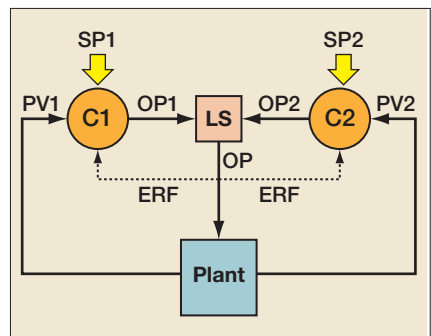


Figure 3 Override control with external reset feedback

back, which prevents windup and ensures that the outputs of all controllers are equal.<sup>5</sup> Figure 3 shows a possible realisation of an over-ride controller with two controllers (C1 and C2), two controlled variables (PV1 and PV2), a low selector, external reset feedback (ERF), and one manipulated variable (OP).

The override control system of MiRO’s fuel gas system is far more complex and has to manage:

- A large number of controlled variables and controllers
- An elaborate structure
- Various requirements (safety limits, optimal operating point, and so on).

As an example, a part of the override control scheme is shown in Figure 4.

**Simulation analysis of many scenarios**

In order to ensure that the objectives shown above are fulfilled, extensive simulation analyses of a wide range of realistic scenarios were performed. For instance, in the case of a sudden shutdown of a 100 MW fired heater at five minutes simulation time the fuel gas system pressure stayed in the stipulated range as shown in Figure 5. The red curve represents the pressure. The

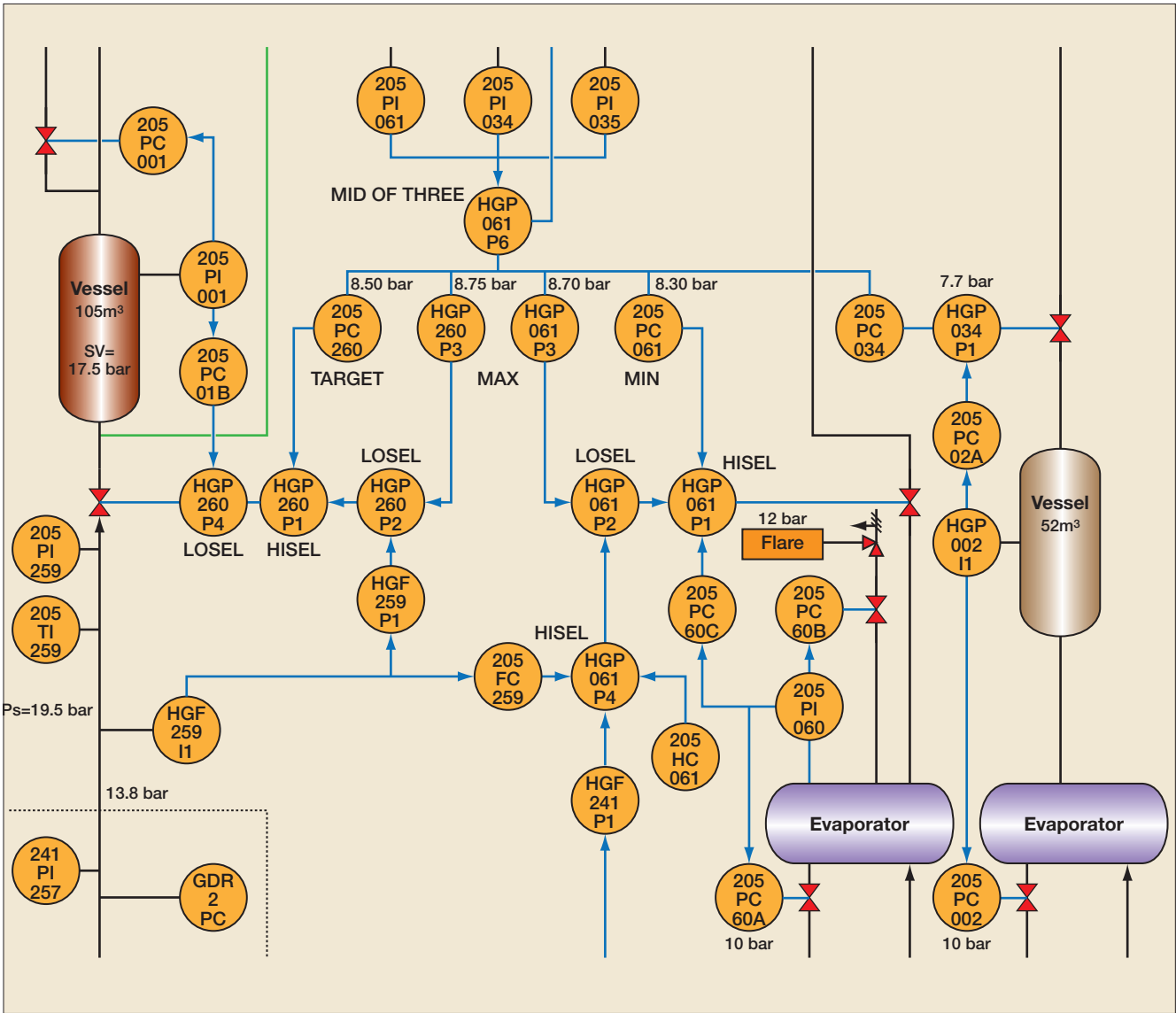


Figure 4 Part of override control scheme of MiRO refinery

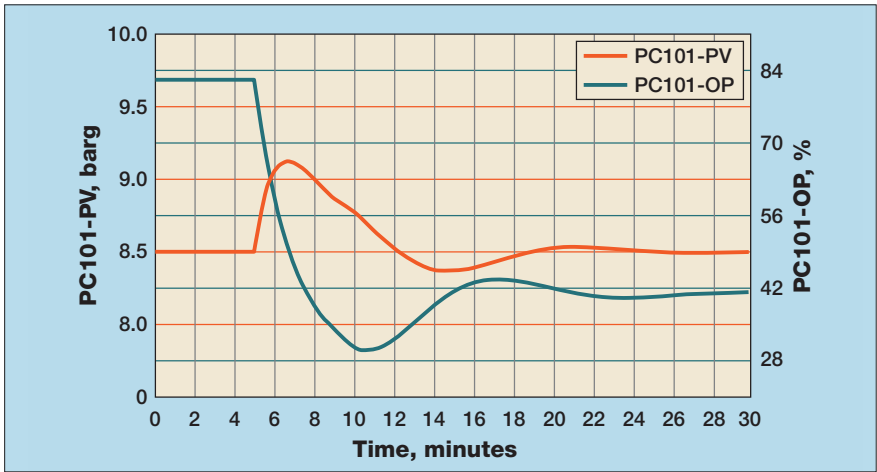


Figure 5 Trend of fuel gas system pressure in the case of a 100 MW oven shutdown

pressure set point is 8.5 bar(g), and the pressure rises up to 9.1 bar(g). The blue curve shows the active OP, which directly controls the valve connected to HGP 260 P4 in Figure 4.

Because many PID controllers are involved, which may interact and cause oscillations, PID parameter tuning was a central point of the simulation analysis. As a result of the investigations, a

number of issues were adjusted such as:

- Pressure limits for flare gas relief
- Valve sizing
- Control parameters.

On the whole, simulation analysis has verified that the design of the fuel gas system, including the natural gas system, and the complex override control system is fully functional and error free.

**Commissioning of natural gas system**

In December 2013, the natural gas system was integrated into the existing fuel gas system. Standard control engineering tasks, such as linearisation of non-linear valve curves, were pursued where necessary. The control parameters which had been designed in the simulation study provided good starting points for detailed parameter

tuning. In many cases, the control parameters of the dynamic simulation could be used without any changes.

As a result of the careful preparation, commissioning went smoothly without any significant problems. It is noteworthy to emphasise the short period of time that was required for commissioning and startup of the expanded fuel gas system.

### Conclusion

MiRO refinery had to expand its fuel gas system for the usage of natural gas as an additional alternative energy source. A new natural gas system, which includes a complex override control structure, was integrated into the historically evolved fuel gas system outside of a shutdown. In order to ensure safe and stable operation of the new system, as well as a smooth startup, a dynamic simulation study of the fuel gas system was carried out using UniSim Design. The simula-

tion study helped to develop a fully functional and error free system. As a consequence, commissioning and start-up of the expanded fuel gas system went smoothly without any significant problems.

UniSim Design is a mark of Honeywell Inc.

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