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Process simulation in industrial projects

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Introduction

Solvina has used Dymola/Modelica since the company started in 1997. During that time we have performed a large number of simulation projects for different customers. Many of our customers are industrial production units and this paper will discuss some experiences of simulating for production units compared to simulation for development or research purposes.

As an example of such a project a steam net simulator that Solvina delivered to Iggesund paperboard will be described.

1 Simulation at Solvina

Solvina AB is a company located in Gothenburg, Sweden. Solvina works with modelling and simulator development. Most of our customers are nuclear, process or power industry but Solvina also work for other customers. Solvina has used Dymola/Modelica since 1997 and it has become our main modelling tool. For our customers we have developed two Modelica libraries:

- SteamNet library
- Pulp&Paper library

The SteamNet library is an extension of the ThermoFluid library and has been used in several projects including the Iggesund simulation project described here. The Pulp&Paper library contains models for both wet end and dry end paper simulation. It has been used to model the entire board machine at AssiDomän - Frövi paperboard.

2 Simulating in industrial projects

This paper describes experiences from working in industrial projects. With an industrial project, a project for production industry with little or none simulation experience is meant. Simulation work in such projects is often part of a larger installation or redesign project. Working in such projects makes extra demands on the simulation studies:

- Clear goal
  Specify in advance exactly what studies the simulator should be used for.
- Convince the organization
  Make the customers organization believe in and use the results from the simulations.
- Limited time.
  The simulation result has to be finished in time for factory start up.

The first point is also an advantage. It simplifies the development of the simulator when it is known exactly what it should be used for.

Another thing to consider is that in this type of projects the simulations have to be directly profitable. It has to be clear that the simulator earns money!

3 The project at Iggesund Paperboard

The simulation project Solvina made for Iggesund Paperboard is an excellent example of an industrial project. Iggesund Paperboard was installing a new control system for their steam distribution system.

Figure 1 Iggesund Paperboard

The steam system is essential for the paperboard production and therefore Solvina was engaged to assure the function of the new control system. Our tasks was:

- Verify the control system design
- Tune the control system for several operating conditions
- Train the operators in the new control system functionality before start up. (Operators were used to non-computer based regulators)

The purpose of a steam system is to deliver steam of the right pressure to steam consumers in the process. To generate steam, boilers are used. In a large steam system the boilers generate steam at a high pressure, which is reduced to lower pressures through turbines and thereby generating electric power.

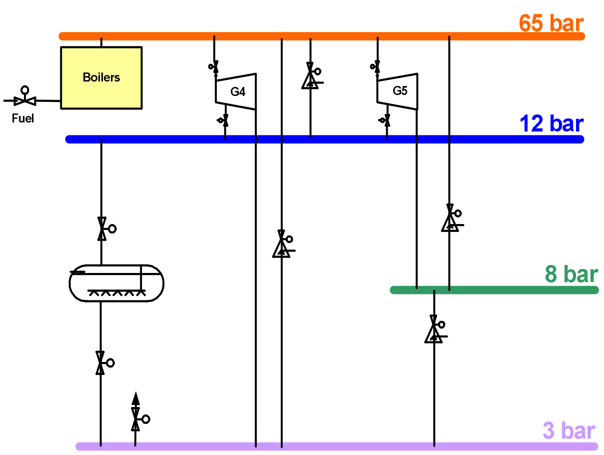

Figure 2 Iggesund steam net layout

The steam net at Iggesund paperboard has four boilers (two recovery boilers, one bark boiler and one oil boiler). The boilers generate high-pressure steam at 65 bar that is reduced through two turbines to three consumer steam nets (3,8 and 12 bar), which supply steam to the process. As a complement to the turbines, valves can reduce steam directly between the different steam nets.

It is important to keep constant pressures in the steam nets because varying pressure affects the quality of the board produced since it gives varying drying conditions in the steam dryer.

The need for steam varies with different consumers turned on and off. An accumulator is installed in the system and can be loaded or unloaded with steam depending on if the need of steam exceeds the production or not. For long term operation the boilers steam production has to be controlled to match the steam need. Boilers however are rather slow to adjust their production so the accumulator has an important role. There is also the possibility to let out steam to the atmosphere (air blow) but then the energy the steam contains is lost.

4 Modelica modelling

Modelling usually starts from a model library. In this case the model was built using the SteamNet library.

Modelling requires a lot of specific data for the process. Good sources for data are drawings and documentation. In process industry logged production data is also often available, which we can use to model already running components.

However it is never possible to retrieve all data needed, but good engineering guesses often function well if checked particularly during validation.

The advantages with using Modelica in this kind of modelling projects instead of traditional flow sheeting programs are several.

- Better dynamical solvers available.
- Models can be modified easily. Flow sheeting programs only have standard components.
- Control systems can be modelled accurately.
- The models can be multi domain.

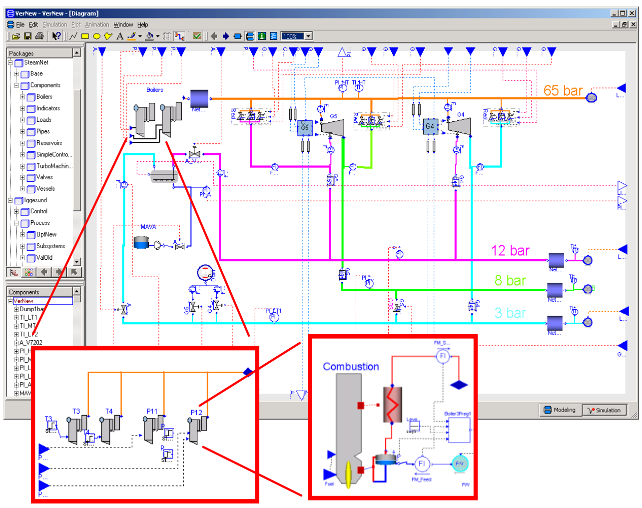

Figure 3 The Iggesund Dymola model

In the Iggesund case, besides the process model, an accurate model of the control system was made including logic for operator control and regulator initiation etc. It would show very important to have an exact model of the control system since many of the problems found in the new control system design was when changing between different control modes etc.

Modelling is often a relatively little part of a Simulation project. In the Iggesund project that totally was about one man-year only 10-15% of the time were modelling. Data collection was about 20% and validation about 30% of the time. The rest of the time was used for simulations with the model.

5 Model description

The model in the Iggesund project was started from the steam net library, which is based on the ThermoFluid library.

From the ThermoFluid library the Medium model for water and the efficient control volume are used. Flows are pressure driven. Static flow conditions are assumed.

The models focus on the dynamics of the process and properties that have importance for the control of the system are more accurately modelled. The valves are modelled with actuators and the flow characteristics of the valves were measured on place.

The boilers were modelled with a transfer function from fuel to heat. The water part of the boiler is modelled with a drum, a convection part and a superheater. The reason for modelling the water part of the boiler accurately was that the evaporation from the drum has an important effect on the dynamics of the high-pressure steam net.

The turbines are modelled as stodola turbines. The turbine control system with limitations for the flow conditions through the turbine was modelled. No account was taken to the inertia of the turbine since the turbine control system always are the limiting factor because it is designed not to allow any flow conditions that can bring instability to the turbine.

6 Validating models

The validation of a model is maybe the most important part. To write models is often a simple and relatively straightforward task. To prove their accuracy and make people believe in the results is often harder.

First the models are validated component by component against operating data or maybe even specially made tests. Next step is validating the model as a system.

To be able to communicate the model with operators and other customer personnel an operator interface is important. This gives all personnel something to gather around. Many interesting discussions often take place when engineers, operators and management are gathered around a tool that allows them to test ideas and discuss them.

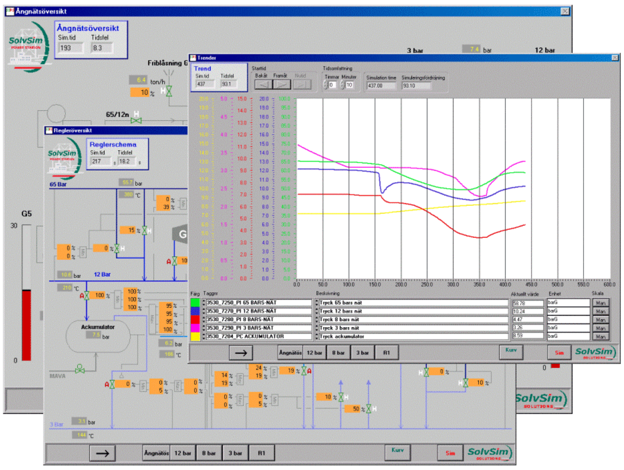

Figure 4 Iggesund simulator with charts

When everyone is convinced that the process model describes the real process system in a satisfying way the models can be used for simulations.

7 Simulations

How to use the models is of course entirely up to what your task is. In the Iggesund project the task was to check and tune the new control system. First the design of the control system was checked. The control system contained about 40 PID regulators that could operate in several modes depending on situation. Directly a few regulators that were misplaced during design were found. They couldn’t function in the control configuration due to system effects even if it appeared logical.

After the design was done the tuning of the controllers started. First a preliminary tuning loop-by-loop was made according to schoolbook methods. After that the entire system was retuned so that it performed well during all different operating conditions. Examples of different operating conditions are high or low production or if one turbine is shut down. In every operating condition the control system should handle a number of disturbances such as board machine shut down, turbine failure etc.

Batch simulations were used to check and tune the control system.

8 Trimming the model

A problem with modelling large Modelica models using libraries is that the models often become stiff. A stiff model is no problem using the good solvers of Dymola although it can be annoying having to wait. However if the model should be used for operator training or in hardware in the loop applications real time performance are needed, preferably using a fixed step solver.

To solve this problem the states with short time constants have to be found and removed. This can be done by linearizing the model and calculating the eigenvalues. The largest eigenvalue will set the limit of the step size for which the model is stable. The linear model is calculated at one time point and the eigenvalues will change for another time point. The calculations will therefore only show the fast states in exactly that time point but can be seen as a hint which states that make the model stiff.

Often it is found that one or a few states have eigenvalues much larger than the rest of the model. It is then often possible to remove or remodel those states. It is seldom time constants bellow a second are interesting in process applications but shorter time constants are often introduced by mistake. For example by introducing a small control volume.

The Iggesund model could be trimmed to run about 10 times faster than real time with a fixed step solver. That was about 100 times faster than the original model just by eliminating fast states. Results of the same magnitude have been achieved with several other process models.

9 Operator training

Solvina has learned not only to deliver correct results, but also to ensure that the customer uses them. Simulator based operator training is one excellent way to ensure that.

For example in the Iggesund Paperboard project the operators must know what incidents the control system is tuned to handle and when they should interact.

Operator training with a simulator not just ensures that the system is correctly used but also gives the operator the ability to test and train incidents and thereby maybe eliminate operator mistakes in the real process. This can be worth as much as the entire simulation project.

Another positive effect with an operator interface is that it gives everyone access to the simulator. It can be used for teaching new operators the system functionality and it can be used for teaching engineers regulator tuning etc.

Figure 5 Operator training (Johanna from Solvina)

Solvina design operator interfaces with our LabVIEW based tool. A screen dump from the real control system is used as background and new figures and buttons are added with drag and drop and coupled to corresponding Dymola values and parameters.

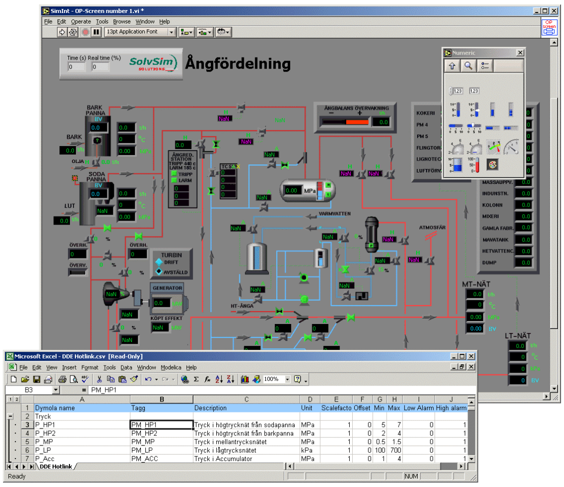

Figure 6 Development of operator interface in LabVIEW with SolvSim – OP-interface tools.

Some of the features incorporated in the operator interface tools are:

- Several operator screens
- Floating dialogs for regulators etc.
- Charts with history
- Stop and save state. Restart from saved state.

It is important that the operator interface is intuitive. It must also have the capabilities needed to investigate the process, that is charts and possibilities to stop/restart.

10 Project Results

The Iggesund Paperboard project was an extremely successful project. The direct results were:

- Perfect start up.
  Everything functioned in automatic mode.
- Not one stop caused by the steam system since.
- Air blow of steam down from 4000 tons/month to 150 tons/month saving 2.5 million liters of oil per year.


AUTOMATION

Noll problem med simulering

Figure 7 Article in "Svensk Papperstidning" about the project "Zero problems with simulation"

11 Next step: Modelica with real control system

In all of Solvinas projects so far the control system has been modelled in Dymola. Although Dymola is suited for this kind of modelling it would be better to use the real control system code. Several advantages can be identified:

- Saving the cost of modelling advanced control systems.
- Debugging the real control system code before start up.
- Even better operator training using the real user interface and operator stations.
- Easier to maintain the simulator if only one version of the control code exists.

A simulator with a steam net system controlled by a Siemens Simatic control system has recently been developed at Solvina. A Modelica model is used, exactly as in previous simulators. The control system model was replaced with an external C function communicating the control signals with an external application.

The external application communicates with the Siemens control system. The control system in this case was run in a software emulated PLC. This makes it possible to run the entire application in one computer and it gives the ability to simulate the same hardware set-up as in the real process.

The reasons to have an extra application between Dymola and the Siemens system are several:

- It can handle start and stop of simulations.
- It can handle time synchronization.
- It can answer simple signals from the control system not simulated in Modelica such as power OK signals etc.
- It can make simple scenarios for fault cases not covered by the model such as fire scenarios etc.

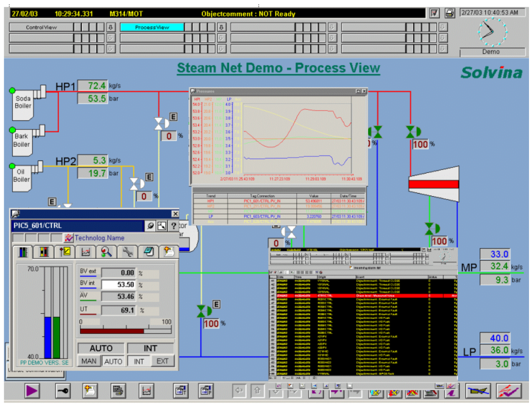

Figure 8 Siemens control system controlling a steam net simulator

12 Conclusions

It is both profiting and stimulating to work with simulations in industrial projects. Working with industrial customers make extra demands on us as having very strict timetables but it also gives us direct feedback from real processes and our results are often directly measurable in money.

An important point when modelling is to have a clear goal for what the simulator should be used for. Far too many simulation projects become long time-consuming projects that finally end almost unused because no clear goal was set in the beginning.

Finally it has to be shown that the simulations are profitable. This however is often clear when a clear goal for the simulations have been set together with a fixed timetable to reach them.

/ Magnus Holmgren, Solvina AB.