

Tutorial

SIMCA-online

Control Advisor in SIMCA-online

30 March 2020

Introduction

SIMCA-online is a real-time prediction system for the process industry. From different types of data sources, such as MES, LIMS and process data historians, SIMCA-online automatically collects data, performs multivariate calculations and generates intuitive control charts that summarize the state of the process. Diagnosis of deviations and alarms are provided through interactive drill down features.

Control Advisor in SIMCA-online extends the real-time multivariate monitoring capabilities to include a Forecast mode for predictive monitoring and an Advised future mode for process optimization with model predictive control (MPC).

Control Advisor includes powerful predictive capabilities utilizing a combination of imputation and regression methods to forecast future trajectories of batch or continuous processes. Predictions of final qualities and yields for batch processes are made available early in the batch evolution and process deviations may be detected before they happen, allowing for proactive corrective action. The Advised future provides suggested process adjustments that may be implemented manually or automatically providing closed loop control.

Objective of the tutorial

The objective of this tutorial is to teach the reader how to install, configure and run the Control Advisor in SIMCA-online. The steps include:

- Uploading a project
- Configuring a model
- Interpreting the results
- Locally turning feature on or off

Prerequisites

The following prerequisites are necessary for this tutorial

- SIMCA-online Server installed as a demo to include the projects and data used in this tutorial.
- Working knowledge how to run DBMaker.¹
- The SIMCA-online user account needs to have permissions to do project administration.²

¹ Information about how to run DBMaker can be found in the document **ReadMe and Installation Guide.pdf**

² The default Administrator user have all permissions

Theory and definitions

To make an informed decision on how to steer a process during production a good estimate of the future, a forecast or imputation, based on historical data and the knowledge on how the system have behaved historically is needed. There are different methods to estimate the future values of a system, but Imputation by Regression (IBR) has proven to be one of the most accurate and fast ones³.

When the Forecast of the future missing dependent variables has been made, optimization algorithms are deployed to find a more optimal future for the system. We call this the Advised future. The optimal setpoints for the manipulated variables found by SIMCA-online can then be applied to the process.

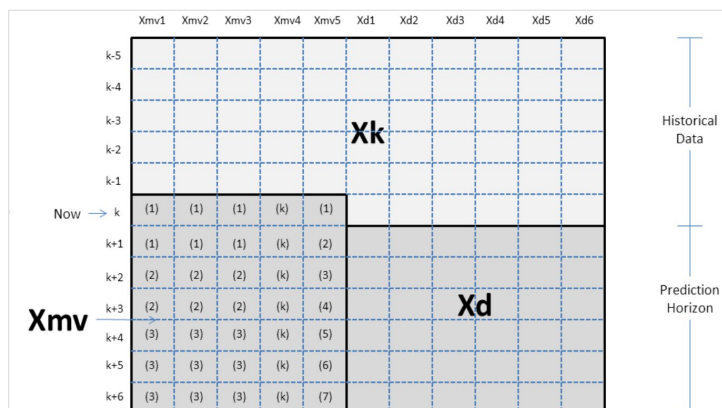


Figure 1: Manipulated variables (Xmv) are future variables that are controllable, and their future settings are known, such as setpoints. All other future X variables are called dependent variables (Xd). All values are known (Xk) up until the current time point.

With good forecasting capabilities, the future setpoints of the manipulated variables for batch processes can be optimized on a few discrete maturities called control maturities for one or more targets, such as:

- Optimizing Y, such as yield or quality (in Batch Level Models, BLM)
- Staying inside the model (in Batch Evolution Models, BEM or BLM)
- Staying close to the average batch from the model (in BEM)
- Keeping a dependent variable close to a trajectory (in BEM)
- Staying as close to the original manipulated variables as possible (in BEM)

For continuous projects, the targets could be to get as small variation as possible.

Note that for the Advised future to work in the Control Advisor, there must be enough variation in the manipulated variables in the historical data to span the region where the optimizer is allowed to work. To ensure this, it is recommended to perform a design of experiments with the manipulated variables at each control maturity.

³ S. Garcia-Munoz, T Kourti, J. MacGregor, Model Predictive Monitoring for Batch Processes, Ind. Eng. Chem. Res. (2004)

Imputation

An imputation is a way to estimate what a missing value in a dataset most likely would be.

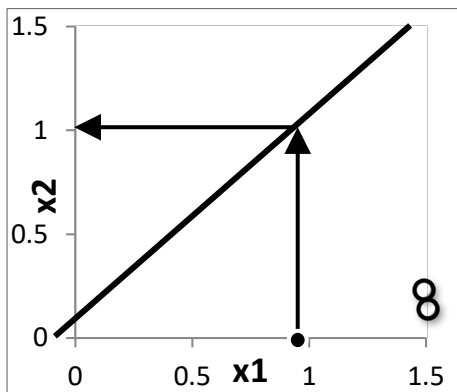


Figure 2: Basic principle of model-based imputation; Estimate the values for x_2 based on a model and the value of x_1 (PMP, SCP and CMR).

In the case for the Control Advisor in SIMCA-online, this means estimating the future dependent variables.

Examples of different imputation methods⁴

1. TRI: Trimmed Score Method
2. II: Iterative Imputation
3. PMP: Projection to the Model Plane
4. SCP: Single Component Projection
5. CMR: Conditional Mean Replacement
6. TSR: Trimmed Score Regression
7. IBR: Imputation by Regression

The imputation method used by SIMCA-online is IBR. All missing dependent values are predicted in a single pass algorithm.

The IBR method for batch processes use a batch level PLS prediction with all variables in the X block and the dependent variables as Y block. The batch level predictions of the Y block are then reorganized back to batch evolution dependent variables.

The IBR method for continuous processes uses a combination of lags and leads where the lagged variables is set to the X block and the dependent variables, the leads, are set to the Y block.

Data

The USP used in this tutorial is the same as the one in the tutorial for creating models for the Control Advisor⁵ and is included (SIMCA project usp file) in the demo installation of SIMCA-online.

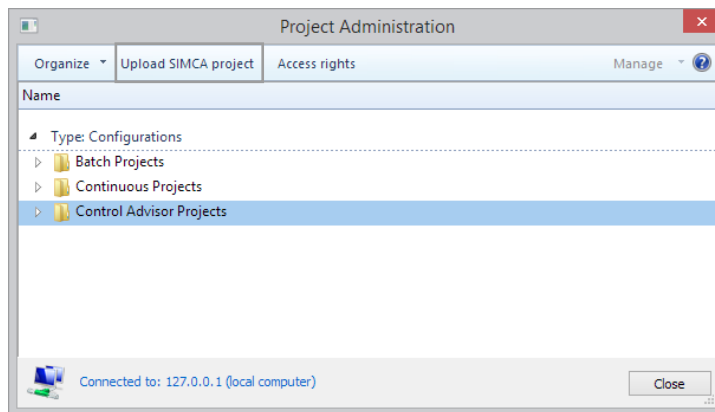
⁴ Arteaga and Ferrer (2002) Dealing with missing data in MSPC: several methods, different interpretations, some examples

⁵ Control Advisor models for SIMCA-online.pdf

Step by step tutorial for Control Advisor

Uploading a project

1. Start DBMaker and use the Start all-button in the toolbar to start publishing demo data and start the SIMCA-online Server.
2. Start SIMCA-online Client and log in as a user with project administration permissions.
3. Open File | Administration | Project administration.
4. Click **Upload SIMCA project**.



5. Select the SIMCA USP project file that contains an imputation model.
6. After the upload is complete, the configuration wizard is automatically opened

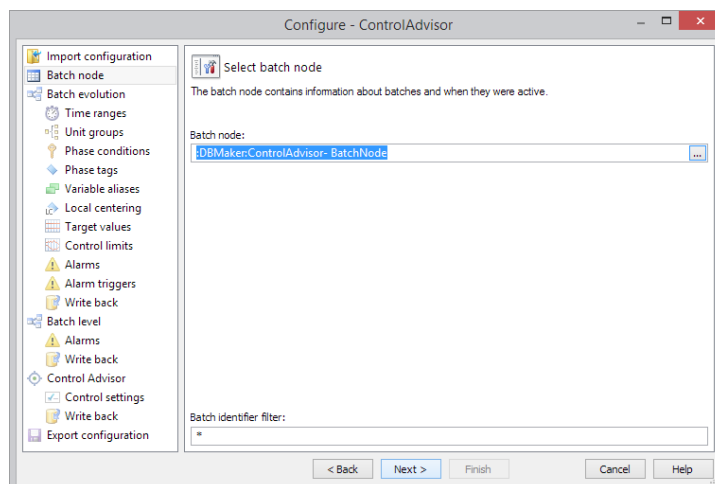
Configuring a continuous project

It is left as an exercise to configure continuous Control Advisor projects. The demo project (and configuration) Proc1aControlDemo.usp that is included in the demo installation of SIMCA-online contain a fully configured project that could be investigated to get more help.

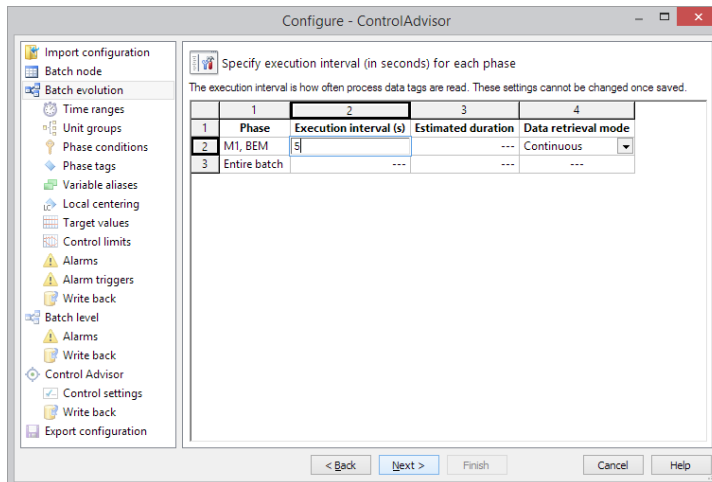
Configuring a batch project

The project configuration below has an already predefined configuration file included in the USP file, which can be loaded in the Import configuration page in the Configuration wizard. If you choose to load an existing configuration file, you can step through the wizard without changing anything.

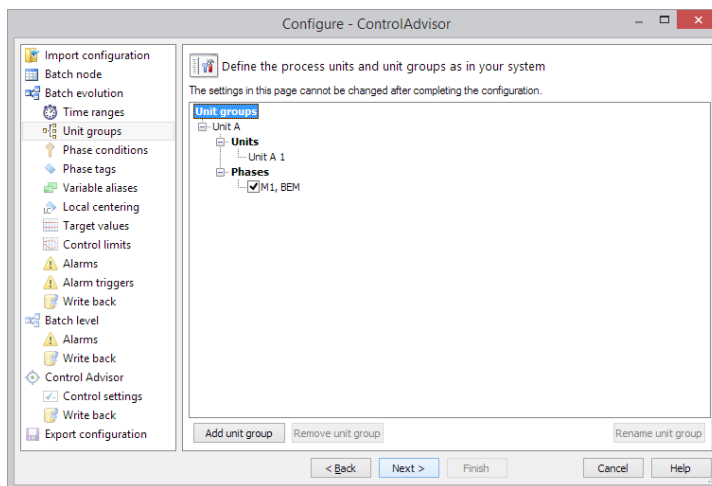
7. Select **ControlAdvisor – BatchNode** as batch node and click Next.



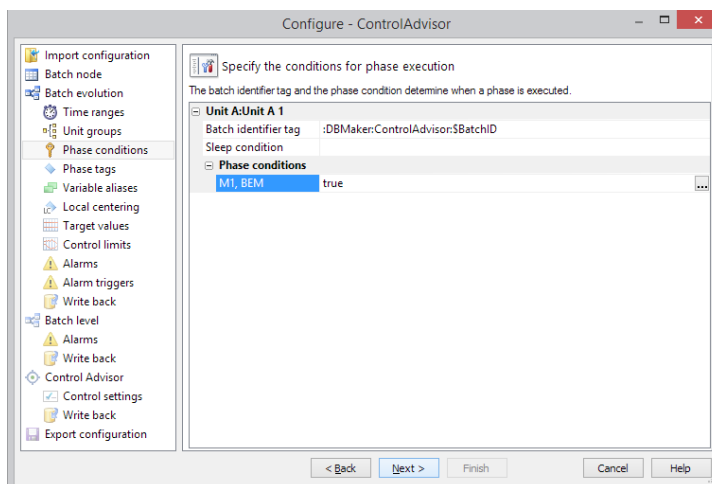
8. Set the execution interval to 3 (s) and click Next, Next. The execution interval then has the same time resolution as set up in DBMaker.



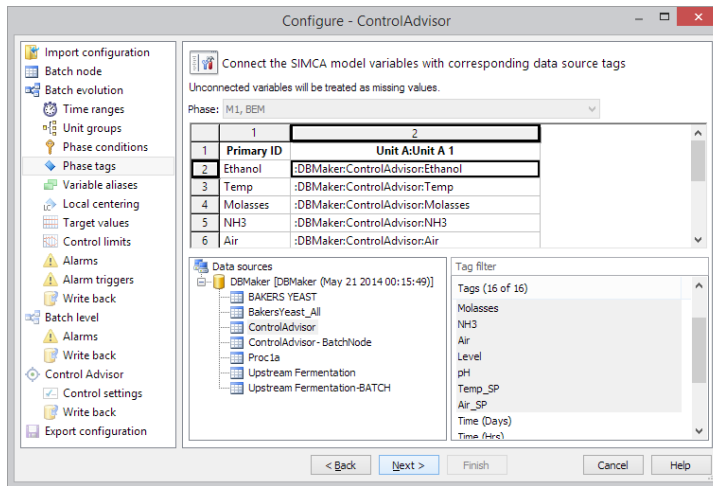
9. In the Unit groups page, click Add unit group, name and select the unit and then click Next.



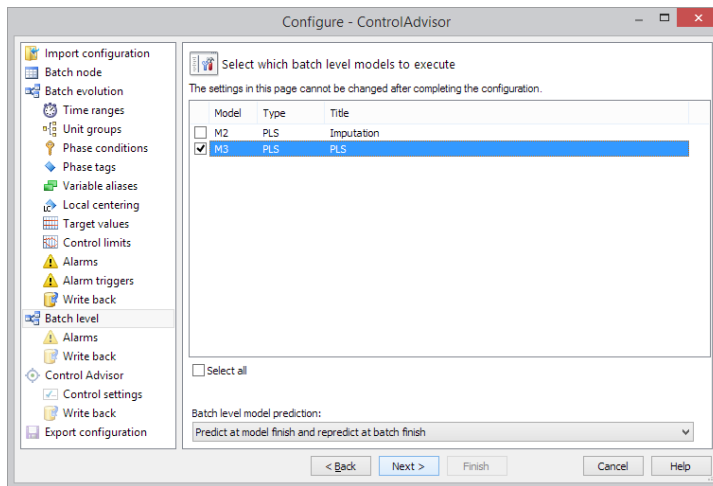
10. Set the Batch ID and phase condition for each phase in the project according to below.



11. Connect the tags to the variables in the model on the Phase tags page. Note that you can Copy/paste from the tag list to the spreadsheet.



12. Next until the Batch level page. Select M3 as the batch level model to execute.



13. Next until the Control Advisor page.

14. The options in the dialog are

Operation – Set to On.

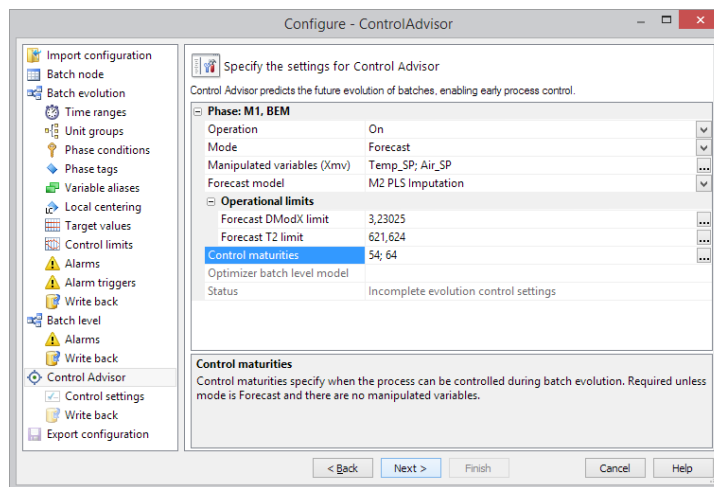
Mode – Select Forecast.

Manipulated variables in this model are **Temp_SP** and **Air_SP**. This is an optional setting that has to correspond to the Forecast model.

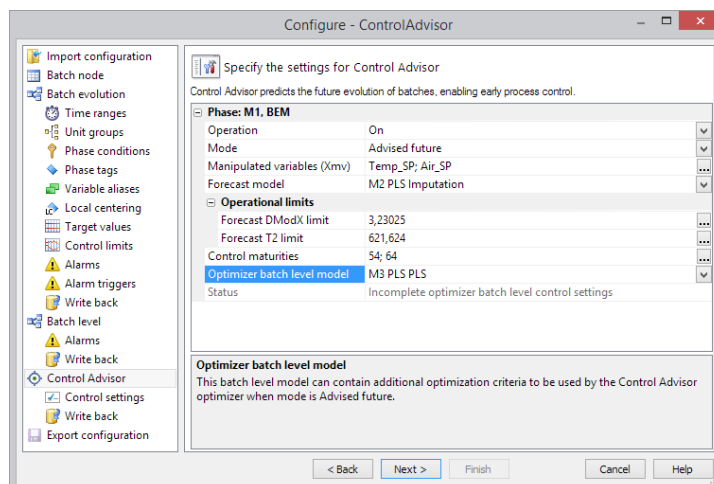
Forecast model included model is called **M2 PLS Imputation**. The number of Y variables must be the number of average observations in a batch times the number of dependent X variables. See separate tutorial for how to create a Forecast model.

Operational limits dictate a cut off when values are too far from the model to be trusted. When the Forecast model prediction is outside these Operational limits, SIMCA-online will not show the Forecast to the user.

Control maturities are the points in time when the system plans a recipe change in the manipulated variables.

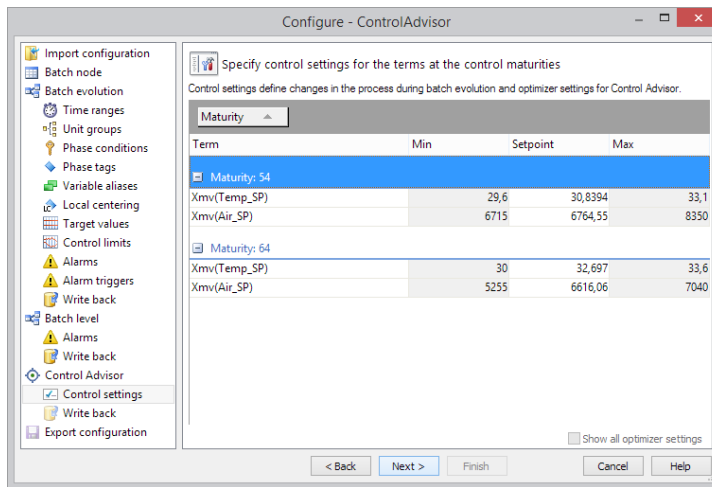


Mode - For the Advised future mode all settings described above apply, plus the additional setting for the optional batch level model. Selecting a batch level model allows specific batch level control using the extended optimizer conditions.



Please note that multi-phase projects will have several phase groups to configure and that there must be one imputation model per phase.

15. For the Forecast mode, only the Min/Max and setpoints for the manipulated variables need to be configured. The setpoints will improve the forecast, while the Min/Max values are only used visually in the univariate variable plots for the manipulated variables.



For the Advised future mode, optionally tune the specific settings for the Control Advisor. All settings have a default. Each of these settings corresponds to a part of the cost function for the optimizer. See the optimizer details in the user guide or help for further information.

There are settings for both the batch evolution and batch level that change the objective for the optimizer. For example, the objective in the evolution level can be to stay close to the average batch while the objective for batch level may be to reach a target, minimum or maximum for a predicted Y.

The settings in the Control settings page are:

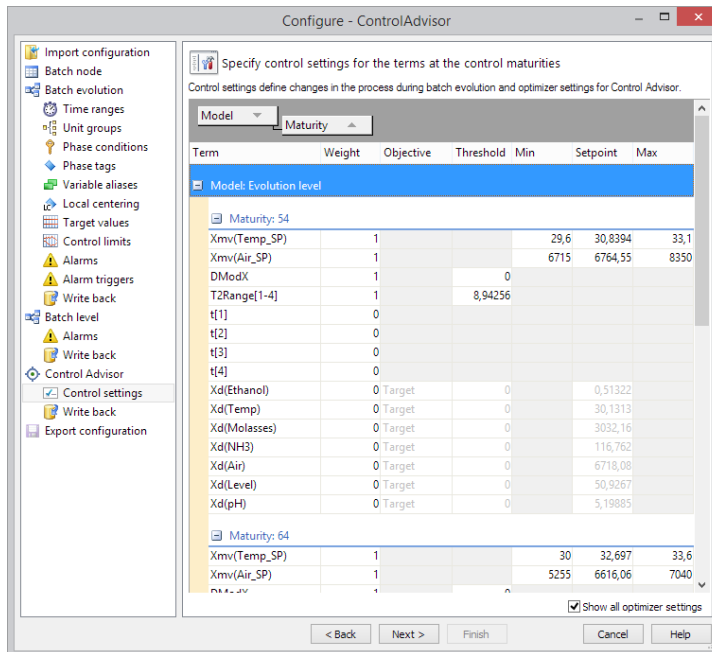
Weight – The higher the weight the more the optimizer tries to fulfil the term associated with the weight. Note that weight 0 means that the term is turned off; range 0 - 1.

Objective – The objective can be either minimize, target or maximize for the dependent variables terms and the y predicted terms.

Threshold – The threshold will create a dead band surrounding the area, meaning that the optimizer can operate freely below the threshold without affecting the optimizer.

Min/Max – The range that the optimizer is allowed to operate within for each variable and maturity. These limits will also be shown in the variable plots for the manipulated variables.

Setpoint – The standard recipe that the process will follow during production if not overridden by the operator.



16. Finish the configuration – you can now start the execution of the configuration and see both the Advised future and the Forecast in batch evolution and batch level plots.

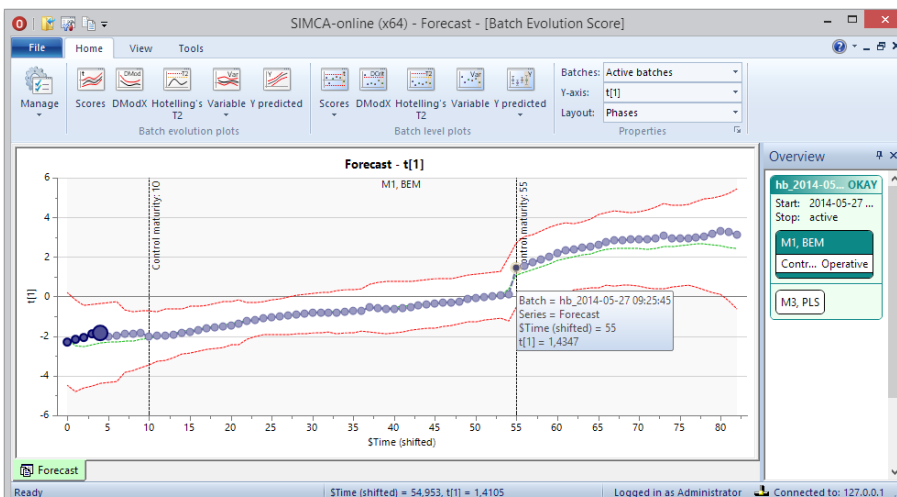
Interpreting the results

There are three different ways to look at the Forecast and Advised future

- In the batch evolution control charts and batch level plots.
- In the overview dashboard for the configuration.
- In the univariate variable plots.

Control charts – Forecast

If the configuration is set up in Forecast mode, the future trajectory of the batch will be shown from the first observation.

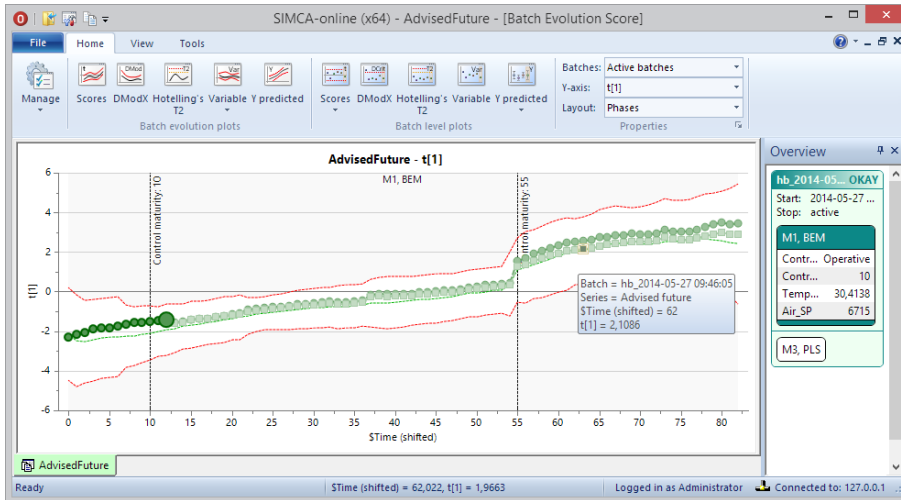


Drill down features are also available for the forecasted values. If no forecast is shown, the batch level PLS prediction is probably out of control. In that case, see the Overview dashboard details in tooltips.

On the batch level, current batches will be semi-transparent until the batch is completed.

Control charts – Advised future

In the Advised future mode, the control charts have two future trajectories. One for the Forecast, which is the predicted trajectory for the process if the recipe is followed, and one for the Advised future, which is the predicted trajectory for the process if the suggested changes to the system are introduced.



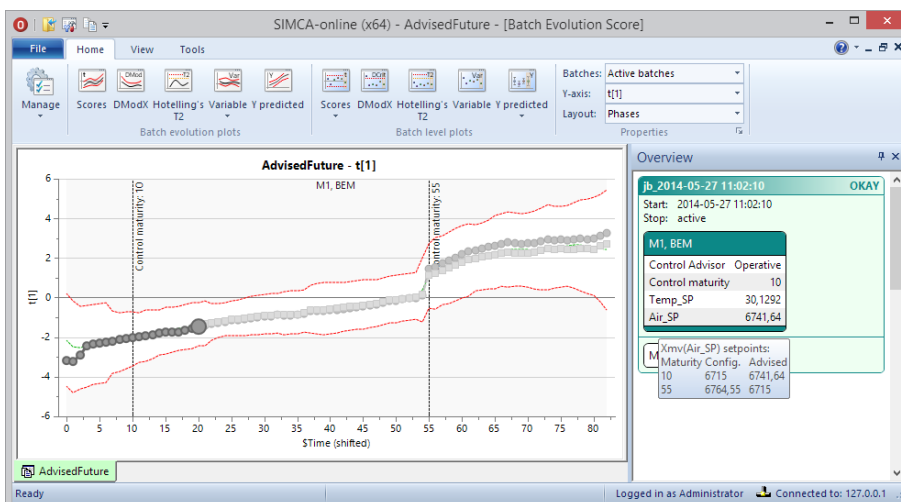
The Advised future is calculated after passing a control maturity. If the Forecast model is out of control, see the Overview dashboard for details in tooltips.

Advised future and Forecast are shown as semi-transparent symbols (boxes, circles) in the same color as the current batch.

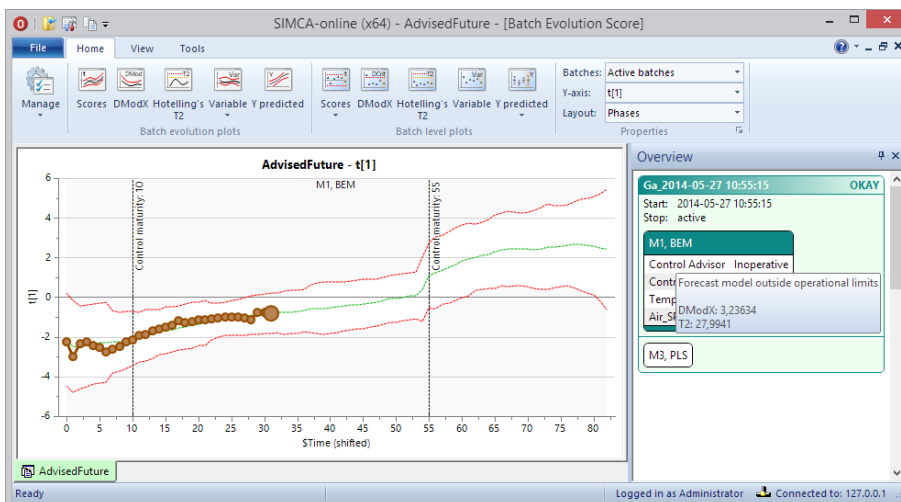
Overview dashboard for the configuration

When the Advised future is Operative, the Overview dashboard will show the latest control maturity as well as the current advised setting for each manipulated variable. For Forecast mode, only the operative status is shown.

The tooltip for the manipulated variables in the dashboard shows the advised setpoints for the last and future control maturities.



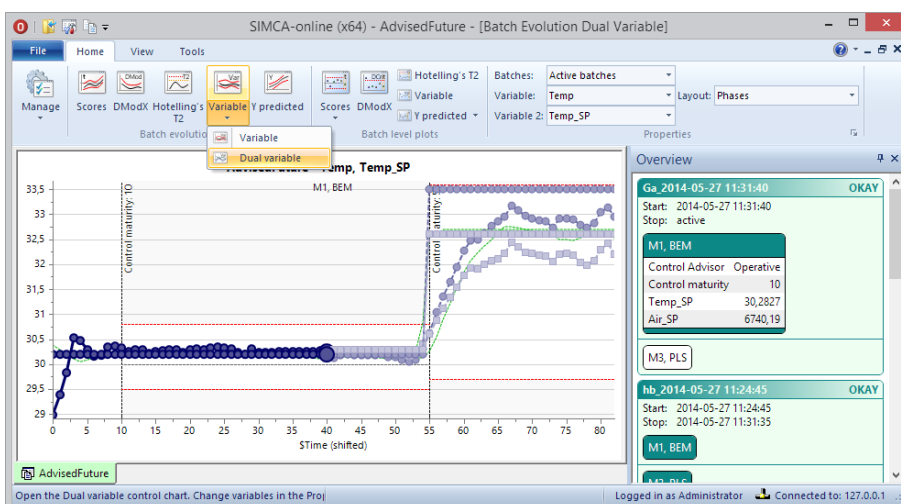
When the batch level Forecast is out of control, the Dashboard tooltip shows the actual values for DModX and Hotelling's T2 for the Forecast model.



Variable plots

To see each manipulated variable with its limits as set in the configuration compared to the actual value as read in from the data source, open the dual variable plot. This plot will show both two variables historical values up to the current time point and then a forecasted and an advised trajectory to batch completion:

- Manipulated variable, here Temp_SP
 - Historical values up to the current time point.
 - Future setpoints according to recipe.
 - Future advised setpoint suggestions from the optimizer after the current time point.
- Measured variable from the process, here Temp
 - Historical values.
 - Forecast.
 - Advised future if the setpoints for the manipulated variables are introduced.



Locally turning feature on or off

You can hide Control Advisor data from an individual plot by right-clicking and in Properties clearing the Show Control Advisor series check box.

You can also change the default options for the client to not show Control Advisor data by default. On the Plot options tab in File | SIMCA-online options clear the Show Control Advisor series check box.

