Application for process automation

Guidelines for the use of the SIMATIC PCS 7 embedded MPC

Notes on use and limitations
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Preface

Aim of the guidelines

The aim is to show a pragmatic approach to simple APC projects. The procedure is explained based on the example of the APC function "model based multi-variable control (MPC: Model Predictive Control)".

The basic steps involved will be shown based on an example from the chemicals industry. Regardless of the many different options available for creating AS or OS functions, the method described here is based on practical experience. In the real world, of course, there are numerous settings possible depending on the specific requirements and restrictions of the customer or the project.

At some points, we will present different approaches without any claim to completeness. At some points a preferred procedure will be introduced, in other situations, the selection depends on certain conditions: application, history, customer philosophy, minimization of implementation effort, minimization of system load etc.

Within a project, a consistent method should be selected and kept to.

The heart of the application

The following core aspects will be covered in these guidelines:

- Recognizing APC applications
- Analysis of the situation
- Creating a control concept
- Identifying the measured data required for the MPC
- Implementation and configuration of the MPC
- Testing the MPC
- Evaluation and conclusions

Validity

… valid for PCS 7 V7.1, in principle transferable to V7.0 SP1.

Reference to Automation and Drives Service & Support

This entry originates from the Internet application portal of Industry Automation and Drives Service & Support. The following link brings you directly to the download page of this document.

http://support.automation.siemens.com/WW/view/en/<entry no>
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3 Analysis of the process
4 Working out the control concept
5 Controller tuning
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10 History
1 Introduction

PCS 7-embedded APC functions
You will find a general overview of the PCS 7-embedded APC functions (Advanced Process Control) in the White Paper "How to Improve the Performance of your Plant Using the Appropriate Tools of SIMATIC PCS 7 APC-Portfolio?" This also describes the basics of Model Predictive Control. http://www.automation.siemens.com/w2/efiles/pcs7/support/marktstudien/WP_PCS7_APC_EN.pdf

You will find the Application Note for the basic uses of MPC here: http://cache.automation.siemens.com/dnl/DQ/DQwODU5AAAA_37361208_Tools/37361208_MPC_en.pdf

Overview of the steps in a project
Figure 1 shows an overview of the individual steps involved in a small MPC project.

![Figure 1-1: Steps in implementation of MPC](image)

The individual steps are described in greater detail in the sections below. This description is intended to serve as a working paper in the projects. The first page of each section therefore serves as a template for the concrete application. The next page of a section then provides the description or an example.
Recognizing potential for optimization and finding APC applications

2 Recognizing potential for optimization and finding APC applications

Works: ____________________________

Name of the plant: ____________________________

Name of the process cell: ____________________________

Name of the unit: ____________________________

Optimization goal 1: ____________________________

Optimization goal 2: ____________________________

Optimization goal 3: ____________________________

Resp. for project: ____________________________

Next step: ____________________________

Next deadline: ____________________________

Remarks: ____________________________
Description:

<table>
<thead>
<tr>
<th>Aims</th>
<th>Participants</th>
<th>Material</th>
<th>Estimated Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finding a concrete application;</td>
<td>Experienced plant personnel, for example participants versed in operational / production routines</td>
<td></td>
<td>Approx. 2 hours</td>
</tr>
<tr>
<td>Defining the person responsible</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The main reasons for using APC are the increase in throughput or yield, improved reproducibility of product quality or saving energy and raw materials costs. The following table shows examples of aims for APC applications according to [1].

<table>
<thead>
<tr>
<th>Aims</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Productivity and economy</strong></td>
<td>Increased throughput</td>
</tr>
<tr>
<td></td>
<td>Minimization of energy consumption</td>
</tr>
<tr>
<td></td>
<td>Reduction of changeover times, for example changing the control strategy, the raw materials or the target products (grade changes)</td>
</tr>
<tr>
<td></td>
<td>Increased yield</td>
</tr>
<tr>
<td></td>
<td>Reduction of processing times</td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td>Improvement of reproducibility and plant control strategy</td>
</tr>
<tr>
<td></td>
<td>(control strategy becomes more uniform)</td>
</tr>
<tr>
<td></td>
<td>Minimization of the range of fluctuation of quality parameters</td>
</tr>
<tr>
<td></td>
<td>Reduction of analysis effort</td>
</tr>
<tr>
<td></td>
<td>Reduction of rejects or lower qualities</td>
</tr>
<tr>
<td><strong>Operability and availability</strong></td>
<td>Increased tolerance relating to fluctuations in raw materials</td>
</tr>
<tr>
<td></td>
<td>Reduction of susceptibility to disturbances or faults</td>
</tr>
<tr>
<td></td>
<td>Increase time between plant shutdowns</td>
</tr>
<tr>
<td></td>
<td>Avoidance of failures and downtimes</td>
</tr>
<tr>
<td></td>
<td>Increased plant availability, flexibility and robustness</td>
</tr>
<tr>
<td><strong>Operability</strong></td>
<td>Smooth operator/shift changeover</td>
</tr>
<tr>
<td></td>
<td>Reduction of workload for the operating personnel</td>
</tr>
<tr>
<td></td>
<td>Increased convenience for operators</td>
</tr>
<tr>
<td><strong>Environmental aspects</strong></td>
<td>Minimization of environmental pollution and volume of residual materials</td>
</tr>
<tr>
<td></td>
<td>Reduction of emissions</td>
</tr>
<tr>
<td></td>
<td>Saving of waste water and sewage</td>
</tr>
</tbody>
</table>
In the process routine, for example, concrete process units could be selected for which one or more of the aspects listed above might have potential for optimization.

Typical questions for the discussion

- Are there aspects in the table above that are currently of concern to you?
- Are you planning concrete energy saving measures that could be supported by APC?
- Do you have fluctuations in product quality?
- Do you want to improve throughput?
- Are you currently planning measures for equipment and instrumentation and could these measures indicate a possible starting point (for example: equipping a cooler with frequency converters etc.)?
- Are there sections of the plant where a lot of manual intervention is required (for example setpoint adaptations) or a lot of PID controllers operating in manual mode that should control automatically to relieve the operators for other tasks?
- Do you have PID control loops that tend to oscillate despite intensive effort in making the controller settings?
- Is there significant interaction between different control loops? Do you have problems setting the individual control loops because changing the controller parameter assignment on a single PID controller has effects on adjacent control loops?

**Notes:**

With first-time applications, look for clearly defined and solvable problems; in other words, do not start with the most difficult problem first.

**Sources:**

3 Analysis of the process

P&ID no.: _________________________

Brief description of the process:

_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________

Brief description of the control strategy:

_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________

Selected operating point:

_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________

Miscellaneous:
Description:

<table>
<thead>
<tr>
<th>Aims</th>
<th>Participants</th>
<th>Material</th>
<th>Estimated Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifying the current situation</td>
<td>Plant manager, process engineer, instrumentation and control technician, plant operator</td>
<td>Screenshots OS P&amp;ID scheme Brief description of the process</td>
<td>Approx. 3 hours</td>
</tr>
</tbody>
</table>

The project manager interviews the persons involved. During these interviews, the relevant information on the current method of operation and any problems is collected.

Collecting this information normally leads to concrete questions, starting points or constraints that must be kept to.

Open questions are also clarified and the next steps decided, for example preparations for the process or instrumentation.

Possible questions that could be asked:

- How does the system currently react to fluctuations caused by changes in inflow and the reflux flow?
- Which interventions are made by the operating personnel?
- Which operating values / control variables are monitored with which priority?
- What tolerances are accepted?
- How is the process handled when load changes occur (for example the column)?
- Based on the OS screenshot, it can be seen that the controllers for the bottom temperature and level are set to MANUAL. Do these controllers just happen to be in MANUAL or is their response too sluggish or do they tend to oscillate?
- How wide or narrow are the tolerance bands of the individual controllers?
- Firstly, how are the 90% light ends in the intermediate container set and secondly how are they monitored?
- How is control changed from container B3A to container B3B and how long does it take if control is changed without shutting down?
- How are pump disturbances currently handled?
• Where does the heating steam originate, in other words is the energy content of the steam subject to fluctuations?
• What influences the differential pressure and how is the limit kept to at the present time?
• How is the cooling capacity of W2 and W3 monitored?
• How is the power for W2 and W3 set? (P&ID was not available)
• Which optimizations of the column are hoped for?

Examples of possible results that could be achieved:

The throughput of the cold brine of W3 depends on power supply fluctuations due to power consumption in the adjacent unit. It was decided to implement the long planned measure on the booster pump to be able to use the volume flow of the cold brine as a control variable. To achieve this the booster pump will be equipped with frequency converters - which will, in principle, allow energy to be saved.

The bottom temperature is not constant but heavily dependent on load. The bottom temperature is therefore always controlled manually. A controller will allow the disturbances (load changes) and interactions (bottom and head temperature) of the column to be taken into account better, the control response and therefore also the product quality should be improved.

In this case, the steam comes from a 30 bar rail and is not subject to fluctuations in its energy content. For this reason, no further measures are necessary in this respect.
4 Working out the control concept

Simplified P&ID: ______________________

Controlled variables: ______________________

Manipulated variables: ______________________

Disturbance variables: ______________________

Miscellaneous: ______________________
Description:

<table>
<thead>
<tr>
<th>Aims</th>
<th>Participants</th>
<th>Material</th>
<th>Estimated Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create a simplified P&amp;ID</td>
<td>Instrumentation and control technician</td>
<td>Screenshots OS P&amp;ID plan</td>
<td>1-2 days</td>
</tr>
<tr>
<td></td>
<td>Specialist department (optional)</td>
<td>Brief description of the process</td>
<td></td>
</tr>
</tbody>
</table>

Based on the analysis from section 3 and taking into account [1], the use of the corresponding APC function is proposed.

The following figure shows the simplified control scheme of the rectification column based on the MPC function block.

Controlled variables:
- Head temperature (CV-1)
- Bottom temperature (CV-2)

Manipulated variables:
- Reflux (MV-1)
- Steam feed (MV-2)

Disturbance variables:
- Inflow (DV-1)
Notes:
Check whether specific preparations are necessary (updates, couplings, etc.).
A checklist simplifies the preparations that need to be made.
Before the next steps are taken, there should be a review of the current status.
5 Controller tuning

Tuning PID controller 1:
Controller ID: _________________________
Controller type: _________________________
Controller parameters: _________________________

Tuning PID controller 1:
Controller ID: _________________________
Controller type: _________________________
Controller parameters: _________________________

Tuning PID controller 1:
Controller ID: _________________________
Controller type: _________________________
Controller parameters: _________________________

Tuning PID controller 1:
Controller ID: _________________________
Controller type: _________________________
Controller parameters: _________________________

Remarks:
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
_______________________________________________________
Description:

<table>
<thead>
<tr>
<th>Aims</th>
<th>Participants</th>
<th>Material</th>
<th>Estimated Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimum setting of the PID parameters</td>
<td>Instrumentation and control technician, Specialist department (optional)</td>
<td>Manual (experience) PID tuner</td>
<td>1 day (depending on time constants, no. of PIDs)</td>
</tr>
</tbody>
</table>

With the PID tuner of SIMATIC PCS 7, the process model and the suitable control parameters can be calculated based on active process excitation. [http://www.automation.siemens.com/](http://www.automation.siemens.com/) "insert PID tuner"
6 Plant test

Date: _______________________

Start: _______________________
Manip./disturb. variable: _______________________
Initial value: _______________________
Final value: _______________________

Start: _______________________
Manip./disturb. variable: _______________________
Initial value: _______________________
Final value: _______________________
Final value: _______________________

Start: _______________________
Manip./disturb. variable: _______________________
Initial value: _______________________
Final value: _______________________
Final value: _______________________

Start: _______________________
Manip./disturb. variable: _______________________
Initial value: _______________________
Final value: _______________________
Final value: _______________________

File name: _______________________

Description:

<table>
<thead>
<tr>
<th>Aims</th>
<th>Participants</th>
<th>Material</th>
<th>Estimated Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recording the process dynamics</td>
<td>Instrumentation and control technician</td>
<td>CFC trend display</td>
<td>Depending on the process dynamics</td>
</tr>
<tr>
<td></td>
<td>Foreman</td>
<td></td>
<td>1 days</td>
</tr>
<tr>
<td></td>
<td>Specialist department (optional)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Recording of test series to find the model (output: EXCEL lists, CSV files)

Notes:

Historical data can be used. If required, suitable manual formatting of the *.csv files needs to be created.

Sources: You will find the Application Note for the basic use of MPC here:

http://cache.automation.siemens.com/dnl/DQ/DQwODU5AAAA_373612
08_Tools/37361208_MPC_en.pdf
Implementation

Date: 

Name of the PCS 7 project: 
MPC-SCL source file: 
MPC FB no.: 
MPC DB no.: 
Cycle time: 
CFC chart: 

Brief description of the modifications in the project:

Done: 

Miscellaneous:

Note: when necessary, several different SCL source files with the MPC controller designs can be generated and tested during operation.
Description:

<table>
<thead>
<tr>
<th>Aim</th>
<th>Participants</th>
<th>Material</th>
<th>Estimated Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation of the application in the control system project</td>
<td>Instrumentation and control technician Specialist department (optional)</td>
<td>MPC configurator SIMATIC Manager</td>
<td>1 day</td>
</tr>
</tbody>
</table>

The basic procedure for commissioning a predictive controller is based on the computer-aided commissioning of PID controllers.

Since the "controller parameters" are matrices, the interaction between the controller block and configuration tool is somewhat differently organized. Configuration involves several steps (refer also to the online help of the ModPreCon block).

You will find a precise description in the Application Notes:

Excerpt from the notes:

- Excite the process with the controller in manual mode by applying a series of manipulated variable step changes.
- Record the measured data with the CFC trend display and export it to an archive file.
- Using the MPC configurator, create an SCL code for the user data block (DB). It contains the models and matrices required for an MPC instance.
- Compile the SCL source code in the engineering system and download it to the AS.

Documentation of the CFC charts in the existing plant and modified OS pictures as well as the most important results of the MPC configurator.
Implementation

APC AddOn-Produkte

Version V1.0 13. Sep. 2010
Commissioning and testing

Commissioning: __________________________

Remarks:
_____________________________________
_____________________________________
_____________________________________
_____________________________________
_____________________________________

Testing phase II: __________________________

Remarks:
_____________________________________
_____________________________________
_____________________________________
_____________________________________
_____________________________________

Testing phase III: __________________________

Remarks:
_____________________________________
_____________________________________
_____________________________________
_____________________________________
_____________________________________
Description:

<table>
<thead>
<tr>
<th>Aim</th>
<th>Participants</th>
<th>Material</th>
<th>Time needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing the MPC application during operation</td>
<td>Plant operator</td>
<td></td>
<td>approx. 3 months</td>
</tr>
<tr>
<td></td>
<td>Specialist department (optional)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In this phase, the designed controller is tested during operation. If the controller has an unsatisfactory response, this may be caused by the controller settings that may need to be modified accordingly (analogous to adaptation of PID controllers).
Conclusions

## 9 Conclusions

<table>
<thead>
<tr>
<th>Benefit Estimation [%] (small projects)</th>
<th>Operation Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>Start-Up</td>
</tr>
<tr>
<td>Remarks</td>
<td></td>
</tr>
<tr>
<td>Control Loop</td>
<td>Variable</td>
</tr>
<tr>
<td></td>
<td>Control Performance</td>
</tr>
<tr>
<td></td>
<td>Service Factor</td>
</tr>
<tr>
<td>Product</td>
<td>Throughput</td>
</tr>
<tr>
<td></td>
<td>Quality</td>
</tr>
<tr>
<td></td>
<td>Yield</td>
</tr>
<tr>
<td></td>
<td>..........</td>
</tr>
<tr>
<td>Raw Material</td>
<td>Educt 1</td>
</tr>
<tr>
<td></td>
<td>Educt 2</td>
</tr>
<tr>
<td>Energy</td>
<td>Power</td>
</tr>
<tr>
<td></td>
<td>Steam</td>
</tr>
<tr>
<td></td>
<td>Fuel-Gas</td>
</tr>
<tr>
<td></td>
<td>..........</td>
</tr>
<tr>
<td>Personnel</td>
<td>Working load/Unit</td>
</tr>
<tr>
<td>Time</td>
<td>Time per batch/action</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Time (days)</td>
</tr>
<tr>
<td>Automation</td>
<td>Degree of automation</td>
</tr>
<tr>
<td>Availability</td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>Emission/Waste water</td>
</tr>
<tr>
<td>Knowledge</td>
<td>Increase practical know.</td>
</tr>
<tr>
<td>Others</td>
<td>Reduce laboratory anal.</td>
</tr>
</tbody>
</table>

Brief survey after approximately 3 months of operation with the finished application. Implement any proposals for improvement.

Explanations of the table:

- A three-line control loop needs to be created for each control variable.
- Plain language comments on the individual operating modes are entered in the experience line.
- The laboratory line contains the proportion of product rejected due to laboratory analyses.
## History

Table history

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1.0</td>
<td>July 26, 2010</td>
<td>First issue</td>
</tr>
</tbody>
</table>
