Some Aspects in Process Automation

Introduction

Trends in Production

Process Analytical Technologies (PAT)

Micro Process Technology

Concluding Remarks
# Siemens Groups

## Process Automation

<table>
<thead>
<tr>
<th>Medical</th>
<th>Information and Communications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical Solutions (Med)</td>
<td>Siemens IT Solutions and Services (SIS)</td>
</tr>
</tbody>
</table>

## Automation & Control

<table>
<thead>
<tr>
<th>Automation and Drives (A&amp;D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Solutions and Services (I&amp;S)</td>
</tr>
<tr>
<td>Siemens Building Technologies AG (SBT)</td>
</tr>
</tbody>
</table>

## Lighting

<table>
<thead>
<tr>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osram GmbH</td>
</tr>
<tr>
<td>Power Generation (PG)</td>
</tr>
<tr>
<td>Power Transmission and Distribution (PTD)</td>
</tr>
</tbody>
</table>

## Transportation

<table>
<thead>
<tr>
<th>Financial Services &amp; Real Estate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation Systems (TS)</td>
</tr>
<tr>
<td>Siemens Financial Services (SFS)</td>
</tr>
<tr>
<td>Siemens VDO Automotive AG (SV)</td>
</tr>
<tr>
<td>Siemens Real Estate (SRE)</td>
</tr>
</tbody>
</table>
# Siemens Groups’ sales in FY 2006

<table>
<thead>
<tr>
<th>Category</th>
<th>Sales (in billions of euros)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communications</td>
<td>13.1</td>
</tr>
<tr>
<td>Siemens Business Services</td>
<td>5.2</td>
</tr>
<tr>
<td>Automation and Drives</td>
<td>12.8</td>
</tr>
<tr>
<td>Industrial Solutions and Services</td>
<td>8.8</td>
</tr>
<tr>
<td>Siemens Building Technologies</td>
<td>4.8</td>
</tr>
<tr>
<td>Power Generation</td>
<td>10.1</td>
</tr>
<tr>
<td>Power Transmission and Distribution</td>
<td>6.5</td>
</tr>
<tr>
<td>Transportation Systems</td>
<td>4.5</td>
</tr>
<tr>
<td>Siemens VDO Automotive</td>
<td>10.0</td>
</tr>
<tr>
<td>Medical Solutions</td>
<td>8.2</td>
</tr>
<tr>
<td>Osram</td>
<td>4.6</td>
</tr>
<tr>
<td>Siemens Financial Services</td>
<td>0.7</td>
</tr>
<tr>
<td>Siemens Real Estate</td>
<td>1.7</td>
</tr>
<tr>
<td>Other operations</td>
<td>4.8</td>
</tr>
</tbody>
</table>

(in billions of euros)
# Business Fields of Automation & Drives

## Process Automation

<table>
<thead>
<tr>
<th>Factory Automation</th>
<th>Process Automation</th>
<th>Electrical Equipment for Buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales growth: 9%</td>
<td>Sales growth: 14%</td>
<td>Sales growth: 5%</td>
</tr>
</tbody>
</table>

A&D is a world leader in all fields of automation and drives for applications in industry and infrastructure.
Some Aspects in Process Automation

Introduction

Trends in Production

Process Analytical Technologies (PAT)

Micro Process Technology

Concluding Remarks
Trends in production

The trends of today will also be a challenge tomorrow!

Trends in the market

- individualized mass products with shorter product life cycles

Goal of the plant operator

- flexible production plants in an ever shorter time

Challenges for the plant constructor

- growing complexity and functionality with increasing time pressure
The Intelligent Factory
Fast response to new product requirements

Introduction
The Intelligent Factory
Fast response to new product requirements

Trends in Production
Process Analytical Technologies (PAT)
Micro Process Technology
Concluding Remarks

Process Automation

Design & Modernization
Holistic Modeling

Operation
Self-optimization & Self-healing

Engineering
Autonomic Components

Commissioning
Self-configuration

Automation and Drives
Siemens AG
2006 – Subject to change without notice

Remarks
Structure of a technological component

The technological component contains all information necessary for their production task

- CAD
- CAE
- Location
- Identity
- Control
- HMI
- MES
- Safety
- Security
- SW Version
- State
- Interfaces
- Computing power
- Maintenance
- ...

... complete description over all levels
Engineering
Generation in the language of the process engineer

The technological component is created in the language of the process engineer

Examples of technological descriptions:

- CAD
- CAE
- Location
- Identity
- Control
- HMI
- MES
- Safety
- Security
- SW Version
- State
- Interfaces
- Computing power
- Maintenance
- ...

Identify location at production start
Process monitoring and APC control for the chemical reaction step
Record flow rate and make available to MES

When 10,000 hours of operation reached, create maintenance message: “Clean tank“
Requirements to describe the Process

Clear process understanding

Scale-up know how for technological components

Knowing the critical quality parameters

Real time release (pharmaceutical industry)
Some Aspects in Process Automation

Introduction

Trends in Production

Process Analytical Technologies (PAT)

Micro Process Technology

Concluding Remarks
Current Situation and PAT Initiative of FDA

„Unfortunately, the pharmaceutical industry generally has been **hesitant to introduce innovative systems** into the manufacturing sector for a number of reasons. One reason often cited is regulatory uncertainty, ....“

„**The scientific, risk-based** framework outlined in this guidance, *Process Analytical Technology* or PAT, is intended to **support innovation** and **efficiency** in pharmaceutical development, manufacturing, and **quality assurance**. The framework is founded on **process understanding** to facilitate **innovation and risk-based regulatory decisions** by industry and the Agency.“

![Guidance for Industry PAT — A Framework for Innovative Pharmaceutical Manufacturing and Quality Assurance](image-url)
Improve Manufacturing Performance

- Better process understanding
- Faster process development / scale-up
- Less deviations from specifications (less lost batches)
- Real time product release
- Productivity increase
- Higher yields
- Flexible processes
- Process Improvements
- Better process control
- Less regulatory effort
- Production plants reach higher capacities
**Process Analytical Technology**

**Innovative: PAT Initiative**
- Online measurement of process data and quality parameters
- Transform analyzer data to quality data
- Real time Release
- Process improvement by better process understanding and better process control by control of critical (to quality) parameters
PAT System Design & PAT Tools

Tools for supporting the PAT principles:

- Process Analyzers
- Process Control tools
- Data analysis & mining tools (Multivariate Data Analysis, …)
- Data collection, storage and retrieval tools
- Reporting tools
- Continuous improvement & knowledge management tools

all linked together into one PAT system architecture, easy to integrate.
Project Example: Paracetamol Synthesis

Paracetamol (Acetaminophen) → Painkiller

Acetic anhydride

Paracetamol

Acetic acid
Process Example: Process Data

NIR Data

Process Data

Lab-Based Data (HPLC-Analysis)
Multivariate Data Analysis

The analysis of relationships between two variables is highly useful and very well understood.

Data collected in science, technology, and almost anywhere else are multivariate, with multiple variables measured on multiple time points.

Multivariate data contain much more information than univariate data and hence, an adequate multivariate characterization is a necessary first step in their investigation.

Example:
\[ Q = m \cdot c_p \cdot DT \]
Experimental design is a strategy to gather empirical knowledge, i.e. knowledge based on the analysis of experimental data and not on theoretical models.

A Design of Experiment (DOE) is a structured, organized method for determining the relationship between factors (Xs) affecting a process and the output of that process (Y).
Multivariate Data Analysis: Principle Component Analysis (PCA)

- Description with one principle component (PC1)
- 3D-Dataset
- Description with two principle components (PC1 und PC2)

Process Automation

Introduction
Trends in Production
Process Analytical Technologies (PAT)
Micro Process Technology
Concluding Remarks
Examples for Multivariate Data analysis

**Process data**

**Principle component analysis (PCA)**

- "e.g. earlier detection of outliers"

**NIR-spectral data**

- a) Quantitative (Calibration / Correlation with lab measured quality data)
- b) Qualitative Prozessfingerprint

**NIR-spectral data**

- Correlation with single component-concentration
- Online Monitoring of concentrations (useful for process control)

**NIR-spectral data**

- Typically process behavior - process fingerprint
- Process control by operating in process tunnel

**Micro Process Technology**

**Concluding Remarks**

---

**Process Automation**

**Introduction**

**Trends in Production**

**Process Analytical Technologies (PAT)**

---

**Automation and Drives**
PAT as Part of the Total Manufacturing Landscape

Process Automation

Introduction

Trends in Production

Process Analytical Technologies (PAT)

Micro Process Technology

Concluding Remarks

ERP

MES

LIMS

DCS

Control

Analyzer + Control SW

Field Equipment

Process

Equation

Equation

Equation

Equation

Equation

Equation
**PAT Hierarchy**

**High Level**
- Enables optimization of the complete process
- Gathers data from all process steps via PAT Base Stations
- Allows to follow up total batch quality and compare with process specifications
- Enables Real Time Product Release

**Base Station**
- Controls one specific Unit Operation
- Input from one or more analytical instruments and process variables
- Used to predict
- Improve process understanding, online process follow-up, control of this specific Unit Operation
Some Aspects in Process Automation

Introduction

Trends in Production

Process Analytical Technologies (PAT)

Micro Process Technology

Concluding Remarks
Just as with Microelectronics, MicroSystem Technology makes Products and Services Possible, that would not be Possible with Conventional Technologies.

1953: First IBM Computer

2000: Techniques in the pharmaceutical industry

Computer Today

Techniques Tomorrow
History of Chemical Industries

Introduction

G. Agricola, *De Re Metallica*, 1556
Micro process technology

This microreactor is not all that small on the outside; its internal workings with micromixers and several tens of thousands of micro-channels are „micro“.

DSM, Linz, Austria, 2005
Specifications of Micro Pressure Sensor

**Ranges**
- Pressure 0 – 30 bar
- Temperature 10°C – 55°C
- Accuracy better 1%
- Resolution 0.02%

**Features**
- Selftest, integrated failsafe operation
- Digital transmission (I²C)
- Overpressure 2x full scale (DIN EN 61010)
- Material Silicon

![Image of silicon micro sensor with labels for Flange-Housing, Adapter-Housing, and Process connection]
Micro structured coriolis mass flow metering

The hydraulic diameter of the tubes is about 800 µm

Coriolis Mass Flow and Density measurement
Devices with three different designs

The hydraulic diameter of the tubes is approximately 800 µm.
Demonstration of density measurements
SIPROCESS – at a glance

SIPROCESS – The modular, open, automated micro process system

Technical features:
- Fluid-fluid reactions
- One or two step synthesis
- Process-related pressure: 25 bars
- Reaction temperature: -30°C to 150°C (expandable to higher temperatures)
- Flow rate per pump module: 0.1 to 50 ml/min, i.e. 70 tons/yr at 8,000 hrs/yr with 3 chemicals
- Material in fluid carrying pathways: stainless steel or alloy C-4, ceramics, perfluorinated polymers and silicon (pressure sensor)

Customer benefits:
- Fast, space-saving installation and modification
- Highly accurate dosing
- Open and flexible for customer-specific solutions
- High reproducibility
- 24-hours operation
- Convenient usability
- User-friendly automation based on SIMATIC PCS 7
- High reliability
Some Aspects in Process Automation

Introduction

Trends in Production

Process Analytical Technologies (PAT)

Micro Process Technology

Concluding Remarks
Concluding Remarks

**General trends in process automation:**

- whenever it’s possible, from macro to micro manufacturing
- PAT change the working models in pharmaceutical engineering and production
- But: Detailed process know how is required to establish the intelligent factory
Thank you very much