Industry 4.0
Basics, controller implementation for plastic machinery and examples of smart factory

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Vertical Market Management
Plastic Industry
Industry 4.0: Basics, controller implementation for plastic machinery and examples of smart factory

Speakers profile

Dipl.-Ing. Thomas Kosthorst
Vertical Market Management
Plastic Industry

- Since more than 25 years in plastic machine controller business
- Working at Beckhoff since 2005
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Introduction to Beckhoff Automation

Headquarters: Verl, Germany
Employees worldwide: 2,900
Number of engineers: 900
Sales/technical offices in Germany: 14
Beckhoff companies worldwide: 34 countries
Subsidiaries and distributors: > 75 countries
Sales worldwide 2014: 510 million € (+17 %)
Sales worldwide 2015 (estimated): ~ 600 million € (+18 %)

as of: 11/2015
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Products and system solutions

- Industrial PC
- EtherCAT Box
- TwinCAT
- Embedded PC
- Bus Terminal
- EtherCAT
- Infrastructure Components
- Drive Technology
- XTS
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Applications and solutions

Plastic  Packaging  Robotic

Forming  Machine Tools  Printing

Wind Turbines  Stage Technology  Semiconductor Manufacturing
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Industry 4.0 – A glance at history

First mechanical loom, 1784

First industrial revolution through the introduction of mechanical production machines driven by water and steam power

End of 18th Century

First conveyor belt, slaughterhouses of Cincinnati, 1870

Second industrial revolution through the introduction of work-sharing mass production with the aid of electricity

Beginning of the 20th Century

First programmable logic controller (PLC), Modicon 084, 1969

Third industrial revolution through the use of electronics and IT for the further automation of production

Beginning of the 1970s

Fourth industrial revolution on the basis of cyber-physical systems

Today

Source: DFKI 2011 (German Research Center for Artificial Intelligence)
The Internet of Things (IoT) is the network of physical objects—devices, vehicles, buildings and other items—embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data.

The IoT allows objects to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit…

Several definitions

1) Combination and interaction of a real, physical system and a virtual representation in the IT-World

2) CPS-based automation systems communicate (at least partly) via open, global information platforms. Through these networks their subsystems and components use resp. provide open available, relevant data and services.

Additionally often CPS-based automation systems are characterized
- By exceeding common system, organization and domain limits
- By changing their heterogeneous structure dynamically during the operation time
- By having the ability for goal-oriented adaptivity and self-modification on basis of model descriptions of their environment and their tasks
- By supporting a consistent, highly model-driven engineering process
Industry 4.0 is identified by smart production

- Smart machine/cell
- Smart factory
- Smart service
(1) A smart machine is an intelligent device, that uses machine-to-machine (m2m) communication technology.

(2) Smart machines includes robots and self cognitive systems, which are able to make decisions and solve problems without human intervention.

(3) Smart machine in total can be understood as a cyber physical system.

Vision of a smart production cell

(First step to I4.0 for Injection molding or blow molding processes)

A number of connected smart machines, ready for m2m technology.
Controller requirements for smart machines

- Open architecture
- Standardized network interfaces
- Wired and/or wireless HMI
- Model based algorithm
- Self learning algorithm
Building blocks of a smart factory are smart machine based on cyber physical systems (CPS) architecture.

A smart factory is defined as a self-organizing m2m based production organization.

A highly integrated production organization, which enables self-organizing production as well as related business procedures. The virtual representation of a factory leads to improvement of efficiency, quality and flexibility.
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The “smart concept”

Controller requirement for smart factory

- Data exchange via network between machines or components
  - enables m2m communication (e.g. via OPC/UA)
  - real time communication via EtherCAT
- Machine are working as “intelligent agents”
- Product identification technique like RFID
- Supports IoT Mechanism
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The "smart concept"

- Improved and extended service using network capabilities as well as computational modeling and simulation for efficient maintenance
- Using augmented reality for faster and target-aimed customer support

Controller requirements for smart services

- Predictive maintenance tools
- Actual machine data communication in real time
- Safe firewall bypass
- Condition monitoring
- Simulation capabilities
- Interface for augmented reality
Features

- PC-based control
- Open architecture
- Convergent with standard IT infrastructure
- Enables object oriented architecture
- Supports all important field-bus architectures
- Supports simulation
- Supports scientific automation, enabling model based approach
- High level programming as well as common PLC language

Software architecture of Industry 4.0 must be more sophisticated than a simple PLC!
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Vision of smart production

Smart Factory

Internet of Things/Services
Cloud Computing
Big Data

Smart Factory
Smart Factory
Smart Factory

Smart Services

World wide web level

Enterprise resource planning system (ERP) level

Manufacturing execution system (MES) level

Machine level

Smart Production Cell
Smart Production Cell
Smart Production Cell
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**Vision of Smart Production**

- **Internet of Things/Services**
- **Cloud Computing**
- **Big Data**

- **World wide web level**

- **Smart Factory**: EtherCAT, Ethernet TCP/IP, Profinet, Profinetz, Ethernet/IP, ...

- **Smart Services**

- **Smart Production Cell**: 3 instances
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Vision of smart production

Internet of Things/Services
Cloud Computing
Big Data

Smart Factory
Smart Factory
Smart Factory

Smart Services

OPC UA
ADS
EtherCAT Automation Protocol

Smart Factory

Smart Production Cell
Smart Production Cell
Smart Production Cell
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Vision of smart production

Smart Factory

Internet of Things/Services
Cloud Computing
Big Data

Smart Factory
Smart Factory
Smart Factory

Smart Services

World wide web level

IoT: MQTT/AMQP
OPC UA
ADS
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Vision of smart production

World wide web level
- Internet of Things/Services
- Cloud Computing
- Big Data

Enterprise resource planning system (ERP) level

Manufacturing execution system (MES) level

Machine level
- Smart Production Cell

Smart Factory

IoT: MQTT/AMQP
OPC UA

Smart Services
Smart machines for advanced production cells

- Raw material handling/control
- Injection molding machine
- Robot/handling
- Quality inspection
- Labeling/packaging

“Smart machines are the building blocks of a smart cell”
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Injection molding controller in I 4.0 environment

Amazon AWS™
Microsoft Azure™
Beckhoff Cloud Service

TwinCAT Analytics
Cloud Storage/Storage Services

TwinCAT Analytics
Workbench

Messaging Services

Euromap77 (OPC UA)
MQTT
AMQP

Cell 1
OPC UA, ADS, EtherCAT Automation Protocol

PC Control

I/O
Fieldbus

Sensor/Actuator

Process
TwinCAT Analytics Logger

Motion
Energy Monitoring
Condition Monitoring
Intelligent Subsystem

Motion
RFID
...Vision

Smart Factory

TwinCAT
Analytics
Cloud Storage/Storage Services

TwinCAT Analytics
Workbench

Messaging Services

Cell x

Smart Factory

Smart Factory

Smart Factory
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Euromap 77 - OPC UA

**OPC UA: Informationsmodelling**

Service Oriented Architecture (SOA) PLC:

- Controller provides **Services**
  Discovery of Services

- **Standardized** Access

Support of

- **Interoperability**
- **Security**: Rolls of access per user
- **Information-Modeling**
  Type and Data consistency
- EUROMAP 63 specifies the data exchange interface between injection moulding machines and central computer/MES
- Data exchange on the basis of text files
- Limited flexibility, speed, … → not ready for Industrie 4.0

- **New interface EUROMAP 77**
  - Basis: OPC UA
  - Namespace-URL provided by Euromap Organization
    - (Only nodes and BrowseNames defined in the standard have the standard namespace. All other vendor specific nodes (types and instances) and BrowseNames have a vendor specific namespace)
Security

- User management
  Configurable access rights for services and data on node level for different groups and users

- Security by design
  - Authentication (X509 certificates, user/password, kerberos)
  - Signing and encryption (SSL)
  - Rights on data point level with audit functionality

→ Already implemented in OPC UA stack - optional use
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Cloud services
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**Scalability and easy maintenance → Cloud Services**

- Azure EventHub
- Azure Topics
- Azure IoT Hub
- Azure Queues

- AWS IoT
- AWS Simple Queue Services
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**Scenario | Who has access to the cloud?**

Every one needs to be identified by **message broker**
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TC3 IoT Communication | Publisher/Subscriber Model

- **MQTT/AMQP Message Broker**
  - Topic
  - Consumer
  - Publisher

- **IPC/Embedded PC**
  - TwinCAT IoT Communication
  - TwinCAT Runtime

- **Private Network**
  - MQTT/AMQP Message Broker
    - Topic
    - Consumer
  - MQTT/AMQP Message Broker
    - Topic
    - Publisher
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**TwinCAT 3 | IoT Functions**

![Diagram showing Windows Azure and Amazon Web Services integration with TwinCAT IoT Functions and runtime.](image-url)
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TwinCAT Analytics for Industry 4.0

- Online and offline condition analysis
- Predictive maintenance
- Pattern recognition
- Machine optimization
- Long-term archiving of data
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**Analytics-Infrastructure**

- Public Cloud
  - Analytics
  - Storage

- IoT Communication
  - Industry 4.0
  - IoT
  - Big Data

- End customer n
  - Local Cloud
  - Analytics
  - Storage

- Machine 1
  - PLC
  - Analytics
  - Storage

- Machine 2
  - PLC
  - Analytics
  - Storage

- Machine builder/Automation
  - Analytics
  - Storage

- 3rd Party Analyst

- 3rd Party Software
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Push technologies via MQTT

Push - Server
  e.g. Google Cloud Messaging

Notifications

TC IoT
TwinCAT Supplement

MQTT

HTTPS, AMQP

FB_TcPush
NetID
Message
Type
DeviceID

Android App on Google Play

12:45

Bluetooth
WiFi

Push technologies via MQTT

Notifications
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Beckhoff Communicator
Requirement for controller architecture

- Open platform
- Convergent to IT-Standard
- Supports deterministic fieldbus architecture
- Supports OPC UA as well as cloud protocols
- Sufficient Performance
- Provides powerful engineering tools
- Includes a robust security concept
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Thank you!
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