”Simulation based engineering and virtual commissioning”

The double for your stars
Simulation of machines, plants and robots in control realtime (<1ms)
Geschäftsfelder – Technologie und Know-how

ISG

**Industrielle Steuerungstechnik GmbH**
Dr.-Ing. Dieter Scheifele

**Field of business**
ISG-virtuos (since 2005)

**Simulation software**
virtual commissioning,
Hardware-in-the-Loop in control real time (1ms),
Simulation-based engineering

**Clients**
Machine and plant manufacturers,
Engineering offices (integrators),
Plant users

> 6,000 machines of different technologies / per year

**Field of business**
ISG-kernel (since 1987)

**Control software**
CNC, RC, Motion Control

**Clients**
Control, machine and plant manufacturers

> 6.000 machines of different technologies / per year
Simulation system
Simulation system – real commissioning on virtual machines

Features

- Commissioning of real CNC/PLC/RC on virtual systems including field bus (HILS)
- Reproducible response times in control realtime (1ms) including SAFETY functions
- Real time deterministic behaviour of the virtual machine on the CNC/PLC/RC field bus
- Interfaces for the Integration of offline programming systems
- "simulation based engineering" thanks to using original engineering data

Real controls
- Beckhoff
- Bosch
- B&R
- Fanuc
- Heidenhain
- Rockwell
- Siemens
- ...

Real field busses
- CANopen
- EtherCAT
- Ethernet IP
- Focas
- Profinet
- Profibus
- + OPC, UDP
- ...

2017-01-18 ISG-virtuos-Präsentation-2017engl.pptx
Requirements of ISG-virtuos clients on control realtime (1ms)

Tendancy: **SPS cycle times** are continuously getting shorter (2, … 4ms)
The reason is not the increased computing power but the automation tasks enabled by the increased computing power:

- **Process control** including **in-process-measuring**
  (Measurement of time-critical process factors, movement synchronization such as „flying saw“, …)
- Test of **control methods** via simulation of control and disturbance variables (clamping forces during gripping and joining processes, process technology, vast disturbance scenarios, …)
- Synchronization of drives of **motion** and **CNC** controls (high demands on tact synchronization, …)
- Simulation of **drive modules** (time-critical „state machines“ as field bus participants)
- **Functional safety**
  (Reaction time on switch-off processes in safety modules, …)
- Grown demands on **result reproducibility**
  (cycle time exact comparison of process values via deterministic realtime, …)
Simulation system – virtual components for automation

Real control

Field bus participant

Real component with realtime behaviour

Real machine / system
(Components, overall behaviour, material flow)

Configuration

Virtual components with realtime behaviour

Virtual machine / system
(Components, overall behaviour, material flow)

1:1 reproduction of components and configuration process
Simulation system – Services with virtual realtime components

WEB services

Field bus

IT network connection

OPC
UDP
TPC/IP

CAM systems ...

Real control

Projection

Virtual components

Configuration

Virtual machine / system

WEB services

Virtual components

Configuration

Virtual machine / system

Virtual components

Configuration

Virtual machine / system

Field bus participant

Virtual components

Configuration

Virtual machine / system
Simulation system – Platform for realtime applications

Commissioning with real controls in control realtime

- System **modelling** from component libraries
- 3D **visualization** by means of original 3D CAD data including configuration
- **Control panels** for the verification of processes and test of disturbance szenarios
- **Realtime simulation kernel** with reproducible results, e.g. for regression tests
- **Control connection** with identical I/O configuration just as on real systems
Simulation system – Fitness of simulation models for virtual commissioning

**Real automation system**
- HMI
- Controls
- Communication
- Components
- System / Process

**Model-in-the-Loop (MIL)**
- Designing of system layouts
- Generic and hardware independent description of control task
- Control and system simulation partially within the same model („windows scripting“)
- Communication mechanisms are not taken into consideration
- Behaviour models are idealized and can only be limitedly used for component tests during virtual commissioning

**Software-in-the-Loop (SIL)**
- Offline programming
- Generation of control code as serial code (e.g. according to IEC61131-3)
- Emulated, i.e. virtualized control
- IT communication mechanisms (shared Memory, OPC TCP/IP …)
- System simulation model often as in MIL
- No realtime deterministic component behaviour
- Only limited use for virtual commissioning incl. FAT

**Hardware-in-the-Loop (HIL)**
- real HMI including all user interactions
- real controls with real control code
- real fieldbus systems (e.g. Profinet, Profinet, EtherCAT including safety)
- Virtual components realtime deterministic behaviour (as field bus participant)
- Virtual system / machine made of virtual components process simulation
Simulation system – integrated engineering processes

Real automation system

HMI

Controls

Communication

Components

System / Process

Model-in-the-Loop (MIL)

Projection
- Designing of system layouts
- Generic and hardware independant description of control task
- Prototypical control code

Software-in-the-Loop (SIL)

Cycle test and program generation
- Offline programming
- Emulated, i.e. virtualized control
- Generation of control code as serial code (e.g. according to IEC61131-3)

Standard communication mechanisms
- Shared Memory
- OPC UA
- TCP/IP ...

Virtual components
- Behaviour models and 3D visualization are strictly separated
- Realtime deterministic behaviour of virtual components (1ms)
- Connectable 1:1 as fieldbus participants (same addressing, same behaviour including safety)

Virtual system / machine of virtual components
- Tool kit system for behaviour models and 3D visualization
- Process simulation / Material flow
- Removal simulation / collision detection

Hardware-in-the-Loop (HIL)

real HMI including all user interactions

real controls with real control code

real fieldbus systems
- E.g. Profibus, Profinet, EtherCAT
- Including safety
- no „gateways“

Standard communication mechanisms
- Shared Memory
- OPC UA
- TCP/IP …
Simulation system – Integration of engineering tools

Projection and programming tools
- ISG CNC.sim
- IFF Vincent
- CENIT FastSuite
- ...

Offline programming systems
- KUKA office lite
- FANUC Roboguide
- ABB RobotStudio
- EKS RobSim
- ...

Standard interfaces (UDP, OPC, TCP/IP)

Projection and layout

3D visualization

Test panels

Realtime solver

Modelling

Virtual commissioning

Integration platform

Module library

SDK C++
## Simulation system – Unique features

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Solution with ISG-virtuos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform</td>
<td>The ISG-virtuos runtime environment runs on industrial control platforms</td>
</tr>
<tr>
<td></td>
<td>- Simulation in hard deterministic <strong>control realtime &lt; 1ms</strong></td>
</tr>
<tr>
<td></td>
<td>- Motion library for <strong>control functions</strong></td>
</tr>
<tr>
<td>Fieldbus connection</td>
<td>ISG-virtuos is a real field bus participant (Profibus, Profinet, EtherCAT, CAN ...)</td>
</tr>
<tr>
<td></td>
<td>- Control uses <strong>original addressing and timing</strong></td>
</tr>
<tr>
<td></td>
<td>(no non-realtime-able gateway to Windows is necessary)</td>
</tr>
<tr>
<td></td>
<td>- Different field busses can be combined</td>
</tr>
<tr>
<td>Safety</td>
<td>Functional control safety can be tested</td>
</tr>
<tr>
<td></td>
<td>- <strong>Safety simulation for I/O and drives</strong></td>
</tr>
<tr>
<td></td>
<td>- <strong>Safety simulation modules</strong> for Profibus, Profinet, EtherCAT</td>
</tr>
<tr>
<td>Material flow</td>
<td>Libraries with material flow including processing simulation</td>
</tr>
<tr>
<td></td>
<td>- <strong>Removal simulation</strong> and <strong>collision detection</strong></td>
</tr>
<tr>
<td></td>
<td>- Material handling during process (<strong>separate/sawing, mate, wire, rolling ...)</strong></td>
</tr>
<tr>
<td>Engineering</td>
<td>ISG-virtuos disposes of an open engineering platform for realtime applications</td>
</tr>
<tr>
<td></td>
<td>- <strong>Software Development Kit</strong> for realtime applications (SDK C++)</td>
</tr>
<tr>
<td></td>
<td>- Integration and <strong>automation interfaces</strong> (OPC, ROS, XML, CAD- and E/A-Import..)</td>
</tr>
</tbody>
</table>
Simulationssystem – Lösung für etablierte Steuerungssysteme

Siemens 840D PL an SCHÜTTE Mehrspindeldrehautomat

FANUC CNC 3ii an GROB-Bearbeitungszentrum

Heidenhain TNC530 an GROB-Bearbeitungszentrum

Beckhoff CNC an Materialflussapplikation mit Roboter

Bosch MTX an GROB-Bearbeitungszentrum

Auszug CNC
Simulation system – heterogene automation scenarios

Simulation of plants / machines with complex automation structures

- Use of real controls of different manufacturers at the same time
- Connection via different fieldbusses at the same time
- Transfer of master E/A configuration via EtherCAT, Profibus, Profinet
- Integrated safety modules
„best practice“ – customers and partners
„best practice“ – Kunden und Partner
Customers on ISG-virtuos

„The only answer to long changeover times is a plant technology that can be established in short time and that can easily handle variant diversity and small lot sizes. At HEITEC we rely on the virtual machine and virtual commissioning with the simulation system ISG-virtuos which has it both: plant and machine simulation as well as 3D visualization in realtime.

Harald Preiml, Directorate, HEITEC AG

„With ISG-virtuos the production cycle time when using new components can be shortened by up to 6 calendar weeks. The construction of the virtual machines works absolutely automatic. Furthermore, we use the virtual machine as a discussion portal within KraussMaffei as well as with our clients and test extreme situations without any risk and reproducible just like on the real machine."

Georg P. Holzinger, General Manager R&D/CTO KraussMaffei Group China

„In companies of the Gleason-Pfauter group the virtual commissioning of machines and automation systems is effected with ISG-virtuos. As a general rule, the simulation of new machine configurations can be configured within 3 days. As such, even complex automation solutions can be flexibly projected and be entirely tested via the simulation model before their production."

Gerhard Krebser, Technical manager, Gleason-Pfauter Maschinenfabrik GmbH
Virtual commissioning – plant and mechanical engineering

HEITEC AG

- Short commissioning times and optimum software quality
- Test of extreme situations without any risks
- Re-use of mechatronic modules
- Generation of improved approval criteria
- Optimization of service and maintenance
- Training and qualification of staff
Virtual commissioning – Wood working plants

WEEKE (HOMAG Group)

- Simulation of safety-critical processes with the real control
- CNC/PLC/HMI module test in advance
- Validation of performance data (FAT with realtime simulation)
- Simulation of extensions after plant delivery
- Model re-use for different model ranges
- Creation of virtual machine within two days
Virtual commissioning – Automation / Configuration

Direct CAD data import
- Machine composition according to skeleton method
- If applicable: simplification (removal of bores / pockets)
- Adoption of anchor points for components via .xml

Use of company-specific libraries
- Model re-use for different components including test of new functions
- Installation of a stationary machine within 2 working days (behaviour model and 3D-visualization)
Virtual commissioning – Machining centers

GROB-WERKE GmbH & Co. KG

- Significantly reduced implementation times
- Professional mastering of failure situations
- Performance validation in dependence to the control components applied
- Removal simulation and collision control
- Test of alternative processes
- Training of staff without occupying the real machine

by courtesy of GROB-Werke GmbH & Co. KG
Virtual implementation – Machine and plant engineering

SMS Group

- Optimization of commissioning costs and time
- Use of real controls without having to change the original PLC software and configuration
- Exhaustion of the maximum possible automation degree
- Return of invest already via the saved material costs incurring during a real commissioning
Virtual commissioning – Injection molding machines

KraussMaffei
  - Machine and plant engineering in the field of injection molding machines

Requirements
  - Detailed test of the various client configurations
  - Electric and hydraulic machine clamping force up to 54,000 kN

Result
  - Process control via control of virtual models in control realtime (<1ms)
  - Automated configuration of control and simulation model according to sales order
  - Simulation (logics, kinematics, dynamics (hydraulics)) of every delivered machine
Virtual commissioning – Research and development

Robot simulation and control

- Academia and research institutions

Task

- Laboratory infrastructure with a technology supporting at best possible conditions the application of robot technology for students and research personnel

Result

- Framework for testing new control strategies on the basis of realtime simulation
- Direct robot activation from ISG-virtuos after having assured the process through simulation
- Significantly shortened project terms
- Using robot technology without risk / intensive support in laboratories
Engineering process
**Objective / Features**

- **Conversion of inflexible, sequential processes into agile „systems engineering“**
- **Software engineering including commissioning** as leading process
- **Virtual plant / machine** is constantly available for dimensioning tests and optimizations
- **Failure situations** are considered from the very beginning
- **Virtual commissioning** can be transferred without limitation on the real machine / plan
Engineering – Organization of machine in functional units

Field bus participant for:
- EtherCAT ¹)
- Profibus ¹)
- Profinet ¹)
- CANopen
- Ethernet-IP

¹) Including safety functionality

Real machine / function units:
- Real field bus components, slaves (E/A and drives)
- Virtual field bus components, multi-slave (E/A and drives)

Virtual machine / function units:
- Identical machine behaviour
Engineering – Visualization (direct import of 3D CAD data)

3D CAD system  ➔  3D geometrics library  ➔  3D visualization

Direct Import of the following formats

<table>
<thead>
<tr>
<th>Format</th>
<th>CATIA</th>
<th>Inventor</th>
<th>Pro Engineer</th>
<th>VRML</th>
</tr>
</thead>
<tbody>
<tr>
<td>NX</td>
<td>SolidWorks</td>
<td>SolidWorks</td>
<td>Solid Edge</td>
<td></td>
</tr>
<tr>
<td>Parasolid</td>
<td>STEP</td>
<td>IGES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JT</td>
<td>VAD-FS</td>
<td>ASIC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Engineering – Component models (from module libraries)

Benefits
- Company-owned library as Know-How set-up and protection
- Validated part-/sub models
- Efficient engineering by re-use
- Process optimization by automated model generation

Real component

Virtual component

Solution / Know-How library

Configuration 1

Configuration n
Engineering – Physics-based material flow in realtime

Automotive / Mounting plants

Conveyor technique

Material flow in machining processes

Pick-and-Place applications

Logistics

Features

- Realtime deterministic behaviour (no “windows scripting“)
- Vast libraries for efficient engineering
- Machining simulation and collision detection included
Engineering – physics-based material flow

Additional benefits

- New physics-based material flow library for efficient engineering
- Applicable for fast processes (e.g. packaging plants with sensor-guided processes)
- Component-oriented and arbitrarily extensible via actors and sensors
- Realtime deterministic behaviour in control realtime (1ms, no „Windows scripting“)
- Free combination of removal simulation and material flow
Engineering – physics-based material flow

EISENMANN SE

- Simulation integration into the engineering process „E-PASS“
- Vast tests in order to secure the requirements
- Virtual commissioning of complex plants
- Great number of controls and components

By courtesy of Eisenmann SE
Engineering – Material flow module libraries

Transportation
- Curved transfer
- Inward transfer (linear-curved)
- Linear transfer
- Outward transfer (linear-curved)

Handling
- Axis (kinematic)
- Element gripper (logical)
- Material gripper (kinematic)
- Stopper (kinematic)
- Stopper (logical)

Motion - Devices
- Motor for conveyor-based transportation (speed controlled)
- Motor for guided transportation (speed controlled)
- Motor for linear movement of elements (move absolute)
- Motor for linear movement of elements (move additive)
- Motor for linear movement of elements (move relative)
- Motor for linear movement of elements (speed controlled)
- Motor for pivot movement of elements (speed controlled)

Actuators
- Actuator for activating logical elements
- Actuator for activating secondary guide
- Actuator for changing pivot point
- Actuator for changing type id of material
- Actuator for delayed switchover between transfers
- Actuator for excluding element behavior for designated material
- Actuator for locking position of elements
- Actuator for varying speed of guided transfers

Sensing / Storing
- Line sensor (straight)
- Surface sensor (rectangular)
- Volume sensor (cuboid-shaped)
- Storage line (cuboid-shaped)

Material Pools
- Material pool (L)
- Material pool (L)
Engineering – Removal simulation and collision detection

Removal simulation
- Precise, photo-realistic display
- Work progress in realtime

Collision detection
- Definition of body pairs
- Display and notification of collisions
Engineering – Configuration from the module kit system

Plant / machine

Configurable modules (video) by courtesy of Weeke Bohrsysteme GmbH

Function areas

Functional units
Engineering – Robot integration / real / virtual

Integration possibilities (e.g. KUKA CNC and Siemens S7)

1. **real control**
   via EtherCAT

2. **Development environment** (Office-PC)
   via UDP

3. **Virtual robot** (OfficeLite)
   via TCP/IP

+ **PLC/CNC** various producers
  via real field busses
Engineering – Robot integration / real / virtual

Robot library
- Approx. 200 types available in standard library
- Detailed 3D geometrics
- Kinematics models in realtime

Producers
- ABB Robotics
- Adept
- Comau
- Epson, Fanuc
- KUKA
- Kawasaki, OTC
- Reis Robotics
- Stäubli
- Universal
- Yaskawa Motoman
Integrated engineering process

1. **Projection** – Plant dimensioning / configuration
2. **Concept development** – Definition of interactions via “teaching“ and testing of processes
3. **CODE generation** – control projects in IEC61131
4. **Virtual commissioning** - in control realtime 1ms, including safety on the field bus
5. **Qualification of control software** – Software regression tests including failure situations and field bus
6. **Digital twin** – Scenarios for service support and staff training
Automation by way of example Siemens/PROFINET (comparable for PROFIBUS and EtherCAT)

1. Generation of SIMATIC S7-Project (Master)
   - Add stations (e.g. SIMATIC 300 station)
   - Add compatible CPU (e.g. CPU 319F-3 PN/DP)
   - Choose Ethernet interface IP address and establish subnet
   - Add/establish PROFINET tools (e.g. ET 200S, PN/PN coupler)

2. Export master configuration (*.cfg) and respective tool master file data (*.gsdml)

3. Generate ISG-virtuos project (multi slave)
   - Import master configuration (*.cfg) via I/O-Wizzards
   - Import tool master file data (*.gsdml)
   - Generate project with I/O tool image
   - Select I/O ports that need to be simulated (mixed mode possible)
   - Generate solver task with linkage on the tool I/Os

4. Simulation with virtual ports as field bus participants
   - Connect virtual I/Os in ISG-virtuos and control (only once)
   - Start simulation and effect virtual commissioning
Engineering – I/O-Wizard for S7 Manager and TIA Portal

Siemens – S7 Manager

Siemens – TIA Portal
Engineering – Connecting models and I/O ports
Engineering – Modelling of drive axes

Modelling of drive axes

Quick access thanks to eligible modelling depth

Goal: „As simple as allowed for the specific simulation task“

- Bypass : „Set = Actual“
- PT1 / 2 : Delay resp. oscillation ability
- Control structure with more than 30 parameters
- Link to MATLAB/Simulink
Engineering – Test and diagnosis functions

Diagnosis and test tools (online):

- Testing control technology with regard to failure scenarios
- Displays, push buttons, switches, scroll bars
- “Scope” functionality to display process data in realtime
- Process data tracking
- Process data provision for further analysis in *.csv format
Engineering – Software Development Kit (SDK C++)

Benefits

- Realisation of own modules also for realtime applications in C++
- Open automation platform
- Executable in TwinCAT 3.1
- Fast familiarization with developer manual
Engineering – Automation test scenarios

Construction data
- Part lists
- Layout
- 3D CAD data

Test environment = real control technology

Client systems
- Client-specific interfaces / formats
- Virtual module library
  - Mechanical modules
  - Electric components
  - Behaviour models
  - Control functionality
- Real modules

Control configuration
- Control software
- E/A configuration

VirtuosM (behaviour model)
- E/A configuration
- Model configuration

VirtuosV (3D visualization)
- Geometry (3D)
- Collision detection
- Removal simulation

ISG-virtuos

ISG-kernel

Client systems
- Engineering assistance (user-oriented)
- Automation (Generators, …)
- Adaption of ext. systems (Translator / mapping)
- Graphic support
- Process generators (Motion, IOs)

XML

Geometry (3D)
- Collision detection
- Removal simulation

Client (AB) / Production

Part lists
- Layout
- 3D CAD data
Virtual commissioning in control realtime

We happily support you in implementing simulation technology in your company.

By means of an introductory workshop, we check the specific requirements for the precise realization of your project at short notice.