Implementation of a CNC machine with Beckhoff-CNC
- Hardware-in-the-Loop simulation in realtime (1ms) with ISG-virtuos -
ISG  Expertise in control and simulation

VIBN  Virtual implementation profitable benefit

ISG-virtuos  Hardware-in-the-Loop in control realtime (1ms)

ISG-virtuos & TwinCAT 3  Virtual implementation with Beckhoff CNC / PLC
ISG Industrielle Steuerungstechnik GmbH

Business areas

**ISG**  
**Business area** ISG-virtuos (since 2005)  
**Simulation software** virtual implementation (VIBN), Hardware-in-the-Loop in realtime (1ms), simulation-based engineering  
**Customers** machine and plant manufacturers, engineering offices (integrators), plant operators

**ISG**  
**Business area** ISG-kernel (since 1987)  
**Control software** CNC, RC, Motion Control  
**Customers** control-, machine- and plant manufacturers
ISG-virtuos - Users / Technology partners
Virtual implementation

- economic benefit -
Virtual implementation

Conventional implementation (sequential workflow)

Engineering
Construction

Construction-specific focuses
- CAD
- FEM
- MKS

Supply
Assembly

Machine / plant not (yet) available for implementation

Implementation
CNC, PLC …

Implementation incl. Factory Acceptance Test

Delivery
Production start
Virtual implementation

Implementation phases

- **V** Basic implementation
  - Basic implementation
    - PLC functionality
    - CNC functionality
    - basic tests
  - Test installation/wiring

- **B** Approval
  - Technology optimization
  - Test safety

- **S** User interface / HMI
  - control sequence
  - special functions
Consequences of missed deadlines in the sequential workflow

- Engineering
- Construction
- Supply
- Assembly
- IBN
- Approval (FAT)
- Technology optimization
- Test / Safety
- Delivery, Production start

- Delay: amendments, clarifications, ...
- Delay: amendments, supply bottlenecks, corrections

No more delays are possible!

Faulty compliance of customer specifications and deficient quality:
- "reworks" on the customers premises during production start
- additional unplanned costs and image damages
Virtual implementation

VIBN – Reduction of processing times and costs

*1) Implementation times reduceable to up to 80% (empirical value of our „best practice“-customers)
Fundamental economic advantages

- **Implementation time** – Reduction of up to 80%
  - shorter production times
  - reduced production hall occupancy

- **Software quality** – considerable increase with same manpower
  - test of regular and irregular operational states, HMI
  - performance can risklessly be increased by alternative processes
  - early bug-fixing saves follow-up costs

- **Risk minimization** in project management
  - quality already achieved in the office
  - customer gets an early insight in the course of project
  - differing requirements are considered in time

- **Cost minimization** during implementation on the customers premises
  - avoidance of collisions, malfunctions and process problems
  - endless test with virtual components and real production data
  - considerable shortening of connection to other automation systems
ISG-virtuos
- Hardware-in-the-Loop in control realtime (1ms) -
ISG-virtuos – Requirements and basic principles of the solution (HILS)

**Real control**
- CNC
- PLC
- Motion control

**Virtual machine**

**Fieldbus**

**Economic process optimization**

1. No extensive and non-conform emulation of the control functionality
   - use of real CNC/PLC

2. Implementation (virtual) and „factory acceptance tests“ without limitations
   - for CNC/PLC, the virtual machine behaves just like the real machine

3. No parallel engineering / simulation process
   - use of original engineering data
HILS in control realtime

Why Hardware-in-the-Loop and control realtime?

The real / original control system can be used / tested without any changes

- deterministic, realistic simulation behaviour – just like the machine on the fieldbus
- reproduceable model behaviour also after various simulation cycles for regression tests
- manufacturer-independant, given the connection via established fieldbus systems
- control configurations (incl. I/O addresses) identic to those on the original machine
How does ISG-virtuos define control realtime?

### Real-time classes and application areas (IAONA classification)

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1µs</td>
<td>Highly dynamic processes, electronic drives</td>
</tr>
<tr>
<td>10µs</td>
<td>Machine tools, fast processes, robots</td>
</tr>
<tr>
<td>100µs</td>
<td>ISG-virtuos</td>
</tr>
<tr>
<td>1ms</td>
<td>Common solutions</td>
</tr>
<tr>
<td>10ms</td>
<td>Conveying systems, simple controls, majority of all automated systems</td>
</tr>
<tr>
<td>100ms</td>
<td>Building technology, control and automation levels, trouble-free processes, storage systems</td>
</tr>
<tr>
<td>1s</td>
<td></td>
</tr>
<tr>
<td>10s</td>
<td></td>
</tr>
</tbody>
</table>

**ISG-virtuos – SINDEX 2014**
TwinCAT 3 as the ideal platform for ISG-virtuos

- Engineering / modeling
- Test panel
- 3D visualization

Windows 32/64 bit

TwinCAT 3

ADS - TwinCAT transport layer

Real behavior

- Dynamics
- Kinematics
- Logics
- MF
- Solver

ADD - TwinCAT device driver

Real controls

- EtherCAT
- Profibus DP
- Profinet
- CANopen
- FOCAS
- SERCOS
- ...
One simulation system for multiple (various) controls

Various simulation / visualization scenarios
- simulation PC with the possibility to connect multiple fieldbuses at the same time – and thus multiple real controls
- multiple controls with multiple simulation PCs and one common visualization possible
- automatic generation of a multi-slave configuration for the representation of control and I/O bus participants of the control configuration
Simulation of complex (distributed) automation solutions

- simulation system easily expandable via fieldbus mechanisms
- combination of Hardware-in-the-Loop-Simulation and real automation systems
- superior 3D visualization of the complete plant
- „Factory Acceptance Tests“ already during implementation
Module library – reusable component models

---

**User / customer know-how setup / protection**
- proprietary library within the scope of “customizing”
- validated part- / sub models
- efficient engineering owing to reuse
- Process optimisation in engineering by automated model generation

---

real components  virtual components

Solution - / Know-how library
Module library – reusable models for 3D visualisation

Virtual component store
- reusable components / assemblies for 3D models (direct import from CAD systems)
- basis for module kit systems
- comfortable generation of new configurations as well as adaption of existing components
- Automatic 3D model generation based on the order-specific machine configuration
Easy configuration process – according to the machine configuration
Removal simulation and collision detection / prevention

Removal simulation
• precise, photo-realistic display
• working progress in control realtime

Collision detection
• definition of Körperpaaren
• collision display and message
Vast diagnosis and test functions

Diagnosis and test tools (online):
- displays, scanner, switcher, slider, ...
- “scope” functionality in order to show process data in realtime
- performance optimisation on the basis of recorded realtime data
- tracking of process data
- Provision of process data for further processing in *.csv–format
ISG-virtuos & TwinCAT 3
- Virtual implementation with Beckhoff CNC / PLC -
Implementation – integrated platform CNC/PLC and ISG-virtuos

Beckhoff
CNC / PLC

Windows 32/64 bit

control HMI

ADS - TwinCAT transport layer

CNC

SPS

TwinCAT 3 runtime

ADD – TwinCAT device driver

EtherCAT

modelling

user interface

3D visualisation (optional)

modeling

logics

kinematics

realtime model calculation (solver)

TwinCAT 3 runtime

ADS - TwinCAT transport layer

ADD – TwinCAT device driver

simulation PC
with ISG-virtuos
Engineering process

Import of 3D geometry data

Engineering steps
- import of 3D CAD data
- visual control of results
- optional model restructuring
- generation of reusable components / assemblies

Engineering support
- direct import from
  - CATIA, Inventor
  - NX, SolidWorks
  - Parasolid, STEP
  - VRML, IGES
- filtering and optimising of 3D data
Set-up of the kinematic model

Engineering steps
- module organisation analogous to the kinematic chain (variances)
- model composition setup from modules
- parametrisation and connection to 3D visual.
- test by configurable control panels

Engineering support
- vast module library with tailored kinematic modules
- simple use thanks to „cut & paste“ sowie „drag & drop“
- no special know-how required
- direct parameter transfer
Modelling of machine functions – functional units (FE)

Engineering process

Engineering steps

- organisation in functional units (FE) with modular hierarchic structure
- attribution of control I/Os to the respective FEs

Typical functional units (FE) of a BAZ

- tool magazine
- tool fixture
- tool spindle
- safety gate
- tool fraction control
- central lubrication, hydraulics, pneumatics
Engineering process

Modelling of machine functions – Realisation of causal loops (FE)

- Construct causal loop with modules (library)
- Assign the internal signals to the control inputs and outputs
- Define parameters
- Store as submodel in library
- Test FEs with respective control panel

Incoming test of FEs by controlling and displaying

"extend_axis" "retract_axis"

"axis_extended" "axis_retracted"
Fieldbus connection – protocols / configuration

- EtherCAT (SW)
- Profibus DP (HW)
- Profinet (SW)
- CANopen (HW)
- Ethernet-IP (SW)
- Safety functionality included

Fieldbus components, slaves (I/O and drives)
Fieldbus components, multi-slave (I/O and drives)
Identical machine behaviour
Fieldbus connection – Generation of I/O configuration

- automatic generation of fieldbus I/O-configurations in ISG-virtuos (Multislave)
  1. direct transfer of master configurations from TwinCAT
  2. resp. import of master configurations for Profibus-/Profinet (*.cfg)
- central I/O module in ISG-virtuos for all required fieldbus I/Os
- easily configurable mixed operation of real and virtual fieldbus attendants via checkboxes
- I/O configurations of various controls can be combined
- All required tasks are automatically instanced as a TwinCAT project
Engineering process

Fieldbus connection – Connection between I/Os and simulation model

- **bit splitting** for easy access on required fieldbus information
- **cycle times** for the fieldbus I/Os can be parameterised flexibly (up to 1 ms)
- **engineering process** can be automated via XML-based interface (ecf- or csv-file)
**Motivation / goal**
- short project life span
- increasing variant variety and high changeover times
- cost and time pressure
- Use of virtual plant / machine for the implementation with real controls
- Visualisation of automation process in 3D

**Main advantages – User and operator**
- short implementation times and better SW quality
- riskless test of also extreme situations
- reuseability of mechatronic modules
- generation of improved acceptance criteria
- Optimisation of service and maintenance
- Training and further qualification of personnel
ISG-virtuos for complex machining centres (BAZ) – Fa. Grob / Daimler

**Motivation / goal**
- BAZ for series production of motor blocks (2 tool spindles, 2 tool magazines with 34 tools each)
- Productivity optimization subject to machine and control technical components
- Optimization of cycle times and professional handling of failure situations
- Reduction of implementation times

**Main advantages - manufacturer**
- Considerably reduced implementation times
- Vast functionality test
- Optimisation and test of alternative processes

**Main advantages - operator**
- Optimization of cycle times (NC programmes)
- Collision control
- Personnel training without machine utilisation
Beckhoff CNC and ISG-virtuos – set-up of the implementation system

- Machine operation
- Engineering and test panel
- 3D visualisation

Simulation scope (WOMAJET F2):
- Kinematics (X, 2xY / Gantry, Z)
- Safety clamp (4x EL1904, 4xEL2904)
- Safety drives (2x AX5805)
- Logics
- Virtual machine control panel
- Component feed and extraction
- Tool: Water jet abrasion
Implementation and test system

Beckhoff CNC and ISG-virtuos – machine operation
Beckhoff CNC and ISG-virtuos – Kinematics and abrasion simulation in 3D
Implementation and test system

Beckhoff CNC and ISG-virtuos – TwinCAT Device-PLC in realtime
Implementation and test system

Beckhoff CNC and ISG-virtuos – Simulation of machine behaviour
Implementation and test system

Beckhoff CNC and ISG-virtuos – TwinSafe applications
Beckhoff CNC and ISG-virtuos – TwinSafe simulation and test
Our offer

- **TwinCAT 3** is the ideal platform for automation technology
- Project engineering with TwinCAT 3 is considerably facilitated by the Automation Interface and the ECAD-Import
- **ISG-virtuos** seamlessly completes the engineering support TwinCAT 3 by adding the implementation of machines and plants with the original control components and in control realtime (1ms)

- Technical discussion can be intensified on the TwinCAT 3 and ISG-virtuos test rig in hall 2 (D.04)
Your ISG-virtuos contacts

Industrielle Steuerungstechnik GmbH
Rosenbergsr. 28, D-70174 Stuttgart
http://www.isg-stuttgart.de

Dr.-Ing. Christian Daniel
Business manager simulation technology
Tel.: +49 711 2299253
Fax: +49 711 2299225
Mobil: +49 173 3432188
Email: christian.daniel@isg-stuttgart.de

Industrielle Steuerungstechnik GmbH
Rosenbergsr. 28, D-70174 Stuttgart
http://www.isg-stuttgart.de

Dipl.-Ing. Ulrich Eger
Abteilungsleiter Simulationstechnik / Prokurist
Department manager simulation technology / Authorized representative
Tel.: +49 711 2299231
Fax: +49 711 2299225
Mobil: +49 175 5451673
Email: ulrich.eger@isg-stuttgart.de

© ISG 2014
ISG-virtuos – SINDEX 2014
Note

Einladung – New Automation Technology Live!
Dienstag, 02.09.2014, bis Donnerstag, 04.09.2014

Vorträge und Präsentationen:

10:00 – 10:45 Uhr  TwinCAT 3 – ECAD-Import, Automation Interface,
TwinCAT-3-Visualisierung, Industrie 4.0
Sven Goldstein, Produktmanager TwinCAT

11:00 – 11:45 Uhr  Inbetriebnahme einer CNC-Maschine inklusive Bearbeitung mit der
Beckhoff-CNC: Hardware-in-the-Loop Simulation in Echtzeit (1 ms)
mit „ISG-virtuos“
Dr.-Ing. Christian Daniel, ISG

13:30 – 14:15 Uhr  AX8000-Vorstellung, Live-Vorführung einer Achs-Optimierung
mittels Bodeplott
Andreas Golf, Produktmanager Antriebstechnik