Simulation Based Engineering
- virtual commissioning -

real-time simulation
Hardware-in-the-Loop - simulation

real controls
- CNC
- PLC
- motion control

fieldbus

real machine

virtual machine
Simulation Based Engineering

Company

Virtual commissioning (process and benefits)

ISG-virtuos – „best practice“ solutions

ISG-virtuos – features and functions

contact
Company - ISG

Company formation: 1987
Registered office: Stuttgart
Field of business: Industrial solutions (focus on software) in the fields of CNC, robotics, motion control and real-time simulation
Personnel: approx. 30 masters of engineering
Customers: control manufacturers, machine and plant manufacturers
Products:
- "CNC/RC kernel"
- "Hardware-in-the-Loop-Simulation"
- "Hardware-in-the-Loop-Simulation"
Our claim

- The business unit (BU) „ISG-VIRTUOS“ offers efficient solutions in the fields of „simulation based engineering“ and virtual commissioning for the machine and plant building.
- The BU „ISG-VIRTUOS“ is technology leader in the field of real-time simulation (Hardware-in-the-Loop)
- The strategy of the BU „ISG-VIRTUOS“ is based on a sustained business model and a customer-oriented product strategy

Mission

- The BU „ISG-VIRTUOS“ is a reliable partner for their customers
- The BU „ISG-VIRTUOS“ mobilizes their entire solution expertise in order to enable the customer to optimize their value-added process with maximum economic advantages
Advantages of cooperating with ISG

- ISG has well-founded experience in **automation technology**, especially in the field of **real-time applications** as well as in fieldbuses including actor- and drive engineering.

- ISG is a technology partner who implements strategic goals together with their customers.

- As a service provider, ISG intensively qualifies the customer’s expert staff already in the solution’s implementation phase.

- For the time being, **ISG-VIRTUOS** is the **only real-time solution** which works with the real control and different fieldbuses time deterministically in a millisecond cycle.

- As a result of the real-time capability of its interfaces, **ISG-VIRTUOS** is available for various different real-time platforms.

- Due to its modular set-up, **ISG-VIRTUOS** enables the users to implement all kinds of realisations: from simple up to complex automation structures.
ISG-virtuos users / technology partners
Virtual commissioning

Hardware-in-the-Loop
Virtual commissioning with HILS – easy to use simulation work station

- Siemens 840D
- Furthermore SIMOTION, S7, Beckhoff, Bosch, FANUC, Heidenhain, ...
- PC with a virtual machine
- Profinet, DPV1, DPV2, ProfiSafe, PROFINET, CANopen, EtherCAT, SERCOS ...

ISG-VIRTUOS – presentation 2014
Virtual commissioning

Clients’ target processes

**Our offer to R&D**
- approved „best practice“-solutions
- implementation of an integrated workflow (mechatronic solutions)
- application of re-useable module libraries

**Main advantages / Benefits**
- product development costs can be cut down by **20%**
- „time to profit“ by **30%** shorter
- solution tests already during concept phase
- reproducible saving effects thanks to solution libraries

**Our offer to Engineering**
- simultaneous engineering based on „best practice“-solutions
- establishment of a professional project management
- re-useable module libraries

**Main advantages / Benefits**
- project costs can be cut down by up to **30%**
- in order to assure quality, also critical functions can be tested in real-time
- proof of function and performance towards the client

**Our offer to Implementation**
- virtual commissioning (VIC) in hard real-time (<= 1ms)
- use of real control components (HILS)
- vast test regarding the compliance with specification requirements

**Main advantages / Benefits**
- implementation times can be cut down by up to **80%**
- shorter cycle time in final assembly and implementation
- no „reworking“ at the clients premises
- riskless training

**Our offer to Production**
- “shadow plant” for the optimization of production processes
- safe use of real machines
- staff training

**Main advantages / Benefits**
- performance optimization by up to **10%**
- material cost savings – test with „virtual components“ and real production data
- prevention of costs caused by collisions and downtimes
Virtual commissioning

Sequential workflow (typical for not using the simulation technology)

- engineering construction
  - engineering specific key aspects
  - CAD
  - FEM
  - MKS

- assembly
  - machine / plant not (yet) available for implementation

- commissioning
  - CNC, PLC ...
  - commissioning including factory acceptance test by the client

- delivery ramp-up
Phases of commissioning (typical)

- **basic commissioning**
  - test Installation/Wiring
  - basic commissioning
    - PLC functionality
    - CNC functionality
    - basic tests

- **HMI**
  - user interface/ HMI
    - Operating sequence
    - Special functions

- **S**
  - technology optimization
  - security test

- **T**
  - approval
Consequences of missed deadline within the sequential workflow

- **Delay:**
  - customer’s addenda
  - need for clarification
  - ...

- **Delay:**
  - div. addenda
  - suppliers as bottleneck
  - corrections

- **No further delay possible!**

**Faulty customer fulfilment and bad quality:**
- „reworking“ at the customer's premises during ramp-up
- additional, unplanned costs / damaged image
Virtual commissioning – reduction of cycle times and costs

*1) commissioning time can be reduced by up to 80% (experience of „best practice“-customers)
Target: Simulation Based Engineering

ISG-virtuos – continuously use as reference / „dynamic specification sheet“
Virtual commissioning

Achievable Advantages

- Reduction of commissioning time by up to 80%
  - shorter project cycle times
  - reduced hall occupation times

- Considerably improved software quality with equal man power
  - test of regular and irregular operating modes, HMI
  - early bug-fix saves follow-up costs

- Risk minimization in project management by „virtual approval“
  - quality is realized in the office already
  - customer gets an impression regarding the project process at a very early stage

- Risk minimization during implementation at the customer’s site
  - collision prevention and prevention of malfunctions and cycle problems
  - continuous test with virtual components and real production data

- Considerable time reduction regarding the connection to superior control systems
ISG-virtuos

„best practice“ – solutions
ISG-virtuós in plant and machine engineering – HEITEC AG

Motivation / Target

- short project cycle times
- increasing number of variations and high changeover times
- pressure of costs and deadlines
  - application of virtual machine for the implementation with real controls
  - plant and machine simulation including 3D simulation

Main advantages – Users and operators

- short implementation times and improved software quality
- test of extreme situations without any risks
- import of CAD-Data and electro configurations
- re-use of mechatronic modules
- generation of improved approval criteria
- optimization of service and maintenance of future plants
- training and qualification of staff
ISG-virtuös for complex machining centre – GROB / DAIMLER

**Motivation / Target**
- machining centre for serial production of motor blocks (2 tool spindles, 2 tool magazines with 34 tools each)
- productivity optimization subject to machine and control technological components
- optimization of cycle times and professional control of failure situations
- reduction of implementation times

**Main advantages - manufacturer**
- significantly reduced implementation times
- vast functionality test
- optimization and test of alternative processes

**Main advantages - operator**
- optimization of cycle times (NC programs)
- collision control
- staff training without machine occupation
ISG-virtuos for CNC-working centres – CHIRON

**Motivation / Target**
- great variety of optional functions
- application of different CNC controls (Siemens, Bosch, Heidenhain, Fanuc)
- test of different configurations
- test of new ideas, e.g. tool change strategies
- shortage of cycle times (order processing)
- increased reliability

**Main advantages – user**
- test of failure situations e.g. „critical“ tool change situations and incorrect tool pre-selection
- „real time“ helps judging the processes
- recognize and measure non-productive times
- a control tested on a virtual machines works on a real machine without any further action
ISG-virtuos for injection moulding machines – KraussMaffei

**Motivation / Target**
- huge variety of optional functions and types in different sizes
- electrically and hydraulically driven machines – closing pressures up to 54,000 kN
- process regulation via the control
- operating points on the real machine hardly reproducible

**Main advantages - users**

(\textit{control cycle = fieldbus cycle = simulation cycle = 1ms})
- automatic generation of simulation models
- simulation of kinematics, logics and dynamics (hydraulic)
- significant reduction of cycle times
- simulation model for each delivered machine
- amortisation of initial costs already within year 1
Motivation / Target
- complex automation tasks with risks at first use of drive and I/O components
- demand for higher reliability of client-specific applications
- necessity to shorten the real implementation times
- reduction of service assignments

Main advantages – user / manufacturer
- test of kinematics, logics, dynamics (hydraulic) and material flow in one simulation model
- reproducibility of regular processes and failure situations in real-time
- considerable reduction of implementation times
- pre-approval on the virtual plant by the client
- sales point: professional engineering
Motivation / Target
- flexible interpretation of production machine
- individual component geometry (lot size 1) with tight deadlines for the entire project
- no buffer for possible disturbance / setup times on the real machine
- project realization does not schedule any „run-up phase“

Main advantages – user / manufacturer
Failure-free and on-schedule production over 3 months in a 3-shift-operation thanks to:
- pre-simulation of each and every process step (no approval without pre-simulation)
- collision control during processing
- visualization
ISG-virtuos
Features and Functions
HILS – Basic principles of the ISG-virtuos solution

- The real control including the real-time features and the fieldbus solution can be used 1:1 → no emulation needed!
- The virtual machine behaves just like the real machine in hard real-time < 1ms → virtual commissioning and „factory acceptance test“ are entirely realizable
ISG-virtuos – client-specific realization options

<table>
<thead>
<tr>
<th>Option</th>
<th>Control</th>
<th>Simulation</th>
<th>Plant / Machine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HILS</strong></td>
<td><img src="image1" alt="HILS Diagram" /></td>
<td><img src="image2" alt="HILS Diagram" /></td>
<td><img src="image3" alt="HILS Diagram" /></td>
</tr>
<tr>
<td>Hardware-in-the-Loop – Simulation</td>
<td><img src="image4" alt="Control Diagram" /></td>
<td><img src="image5" alt="Simulation Diagram" /></td>
<td><img src="image6" alt="Machine Diagram" /></td>
</tr>
<tr>
<td><strong>1-computer-solution</strong></td>
<td><img src="image7" alt="Control Diagram" /></td>
<td><img src="image8" alt="Simulation Diagram" /></td>
<td><img src="image9" alt="Machine Diagram" /></td>
</tr>
<tr>
<td>control computer as simulation workstation</td>
<td><img src="image10" alt="Control Diagram" /></td>
<td><img src="image11" alt="Simulation Diagram" /></td>
<td><img src="image12" alt="Machine Diagram" /></td>
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<tr>
<td><strong>control-integrated simulation</strong></td>
<td><img src="image13" alt="Control Diagram" /></td>
<td><img src="image14" alt="Simulation Diagram" /></td>
<td><img src="image15" alt="Machine Diagram" /></td>
</tr>
<tr>
<td>simulation as add-on value of the machine control</td>
<td><img src="image16" alt="Control Diagram" /></td>
<td><img src="image17" alt="Simulation Diagram" /></td>
<td><img src="image18" alt="Machine Diagram" /></td>
</tr>
</tbody>
</table>
HILS - **Real** control controls virtual machine in control real-time
HILS – Proven solutions for all established control systems

- Siemens 840D Pl on SCHÜTTE multi-spindle automatic lathe
- FANUC CNC 31i on GROB-machining center
- Heidenhain TNC530 on GROB-machining center
- Beckhoff CNC on material flow application with robot
- Bosch MTX on GROB-machining center
## Benchmark: ISG-virtuos *

<table>
<thead>
<tr>
<th>Criterion</th>
<th>USP</th>
<th>ISG-virtuos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handling</td>
<td></td>
<td>• look &amp; feel of a normal Windows application</td>
</tr>
<tr>
<td>Software platform</td>
<td>✓</td>
<td>• modern 64-bit- architecture in the field of visualization and real-time application</td>
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<tr>
<td></td>
<td></td>
<td>• no restrictions regarding size of 3D models</td>
</tr>
<tr>
<td>Real-time ability</td>
<td>✓</td>
<td>• hard real-time ability (&lt; 1ms)</td>
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<tr>
<td></td>
<td></td>
<td>• uses Beckhoff TwinCAT for hard deterministic real-time simulation</td>
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<tr>
<td>External interfaces</td>
<td></td>
<td>• automated model building with XML-files</td>
</tr>
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<td></td>
<td></td>
<td>• export in established file formats of monitoring data</td>
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<tr>
<td></td>
<td></td>
<td>• import of CAD data for 3D display</td>
</tr>
<tr>
<td>Fieldbus support</td>
<td>✓</td>
<td>• Profibus / Profinet</td>
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<td></td>
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<td>• CAN / CANopen</td>
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<td>• EtherCAT</td>
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<td></td>
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<td>• Ethernet/IP</td>
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<td>• SERCOS</td>
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<tr>
<td>Component - / Part geometry</td>
<td>✓</td>
<td>• geometry model can be modified dynamically</td>
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<td></td>
<td></td>
<td>• even complex automation systems can completely be simulated in real-time</td>
</tr>
<tr>
<td>Coupling MATLAB/SimuLink</td>
<td></td>
<td>• direct Import of .m-files</td>
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<td></td>
<td></td>
<td>• Simulation without local MATLAB installation is possible</td>
</tr>
<tr>
<td>Simulation implementation</td>
<td></td>
<td>• detailed requirement analysis regarding tools and project organization</td>
</tr>
<tr>
<td>Training</td>
<td></td>
<td>• staff training/coaching during a workshop on the concrete client project</td>
</tr>
<tr>
<td>After Sales support</td>
<td>✓</td>
<td>• fast assignment at the client’s site</td>
</tr>
</tbody>
</table>

*) Benchmark and USP of ISG-virtuos drawn up by vendors of simulation systems
### HILS – real-time requirements on the simulation technology

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

|                 | 1µs  | 10µs | 100µs | 1ms  | 10ms | 100ms | 1s   | 10s
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<tr>
<td><strong>ISG-virtuos</strong></td>
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<tr>
<td><strong>Machine tools</strong>, <strong>fast processes</strong>, <strong>robots</strong></td>
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<tr>
<td><strong>Conveying systems</strong>, <strong>simple controls</strong>, <strong>majority of simply automation systems</strong></td>
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<tr>
<td><strong>Building technology</strong>, <strong>control an automation levels</strong>, <strong>trouble-free processes</strong>, <strong>storage systems</strong></td>
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<tr>
<td><strong>Highly dynamic processes</strong>, <strong>electronic drives</strong></td>
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</table>
HILS – Why a real-time system for simulation?

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

- control configuration (I/O addresses included) identical to the original machine
- deterministic, realistic simulation behaviour regarding control and fieldbus (~ 1ms)
- reproducible model behaviour on various simulation courses
- manufacturer-independent because of established fieldbus systems
Product – Features and Functions

One simulation system for multiple (different) controls

Different simulation/visualization scenarios
- simulation PC provides the possibility to link multiple field-busses at the same time and thus multiple real controls
- multiple controls with multiple simulation PCs and a common visualization
- automatic generation of a multi-slave configuration for representation of drive and I/O bus members of the control configuration
Simulation of complex (distributed) automation solutions

Integrated test / simulation of complex 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 entire plant
- "Factory acceptance tests" already during commissioning phase
Individual module libraries for the creation of behaviour models

Know-how-buildup /-protection for users / clients

- company-owned library in line with „customizing“
- validated parts-/ sub models
- efficient engineering by means of re-use
- process optimization in engineering by automatic model generation
Module library for 3D visualization

Virtual component inventory
- reusable components / assemblies for 3D models (direct import from CAD-systems)
- basis for modular construction systems
- comfortable generation of new configurations and adaption of existing components
- automatically generation of 3D-models based on the order-specific machine configuration
Product – Features and Functions

Machine configuration – virtual module- / aggregates library

Basic machine

Aggregates
B
C
D
E

Config. #n
• Basic
  + Comp. D
  + Comp. C
  + Comp. C
  + Comp. B
  + Comp. E
  - ...

automatic generation of
  ▪ comprehensive model
  ▪ control configuration
Product – Features and Functions

Machine configuration – configuration process
Product – Features and Functions

3D visualization – with different „camera views“
Real-time simulation of interlinked plants / material flow

virtual production lines with real control technology
Real-time simulation of material flow

**Material flow**
- object generation
- modification / processing of these objects
- deletion of primitive and complex geometry objects
Removal simulation and collision detection / avoidance

**Removal simulation**
- precise, photo-realistic display
- work process in real-time

**Collision detection**
- definition of compound pairs
- display and notification of collisions
Diagnosis and test functions

Diagnosis and test tools (online):
- displays, scanners, switches, scroll bars...
- “scope” functionalities that display the process data in real-time
- process data tracking
- allocation of process data for further analysis in *.csv format
Modelling of drive axes

Fast engineering by the use of selectable modelling depth

Target: „As easy as allowed for a simulation task“

- bypass : „Target = Actual“
- PT1 / 2 : Delay respectively ability to oscillate
- controller with > 30 parameters
- interface to MATLAB/Simulink
Automatic model generation – user-specific engineering tool

Automation of engineering processes:
- individual configurable machines on the basis of a modular construction system with re-useable assemblies / aggregates
- automated control configuration of the control system and the simulation model according to client's order
- assignment of simulation system via setting interface (XML)
Product – Features and Functions

One-computer-solution for control (CNC, PLC …) and simulation

Cost-efficient control system with integrated real-time simulation

- working process optimization without blocking or endangering the machine
- “shadow plant” for collision avoidance
- vast diagnosis possibilities
- process visualization of hardly accessible machine areas (drizzle …)
Contact

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