# Control using Beckhoff distributed rail systems at the European XFEL

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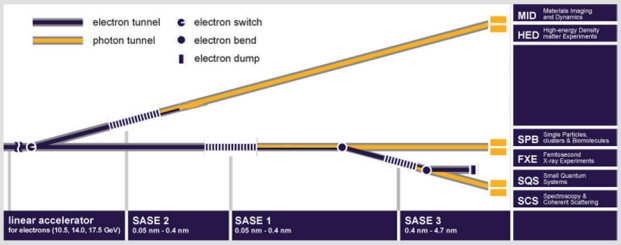
additional Information

## European X-ray Free-Electron Laser Facility

- An ESRFI project, whose construction started in January 2009 in Hamburg, Germany.
- Intense, ultra short and coherent X-ray flashes generated will be used to investigate nm-scale structures, fast processes, and extreme states, taking 3D images of viruses or proteins, and filming chemical reactions.
- From 2016 six experiment stations will operate at three of the five beam lines under construction.
- Flashes are delivered at 4.5 MHz for periods of 600 µs with a nominal 10 Hz pulse train repetition rate.
- The 10 Hz train clock synchronizes data transfer and processing during the following 100 ms time bin.

## Photon system control layout



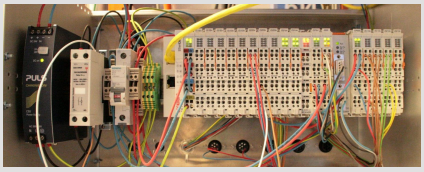

- Sub-partitioning, control rings: 3x SASE, 5-10x experiment.


## Beckhoff Solution

- COTS
- Beckhoff PLC Real Time under Windows
- Provides a flexible, and scalable system
- Integrated Distributed Clocks and Synchronization
- Real-time Ethernet fieldbus EtherCAT
- Cable and CPUs redundancy mechanisms
- TwinCAT IEC61131-3 ST programming
- Numerical Control (NC) library PLCopen compliant
- TCP/IP server via Beckhoff library
- Support for RS232, RS422, RS485, Profibus, modbus, etc
- Homogeneity w.r.t. SASE Undulator controls

## Rail based system

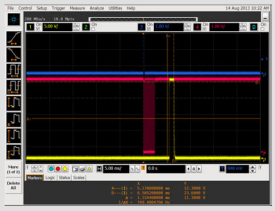
Industrial DIN-rail system, mountable inside a 19'' crate, high density, each terminal (12 mm or 24 mm wide) can control or monitor: Digital or Analogue Input/Output signals, DC/Stepper motor or serial I/O.
Interconnection between rails via CAT5 (max 100 m distance) or optical fiber (max 20 km)



## Timing interface to Linac Clock & Control Metadata

Control CPUs receive via ETA board

- Macro-bunch number and MPS status (Train load pattern information)

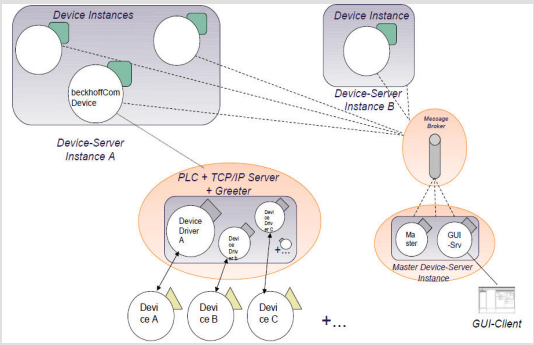


## PLC Framework

PLC in charge of equipment safety

- Check proper version on target CPU at run-time
- Auto upload of precompiled PLC f/w versions
- in-house developed firmware devices:
  - Recognition of mismatch actual vs expected terminal type
  - Complete configuration down to terminal parameters
  - Functional blocks for each device type
    - motor(s), pump(s), valve(s) ,,,
  - Implementing Finite State Machine (FSM)
  - *forceTo* mechanism
  - Sequencing
- Interlock functionality
- Persistency of values (example: last reached position or last *setTarget* working point)

## Beckhoff PLC to Karabo integration




### In-house Development

**Software Devices (C++/phyton class):**

- Reflection of f/w device
- FSM (Boost MSM)
- Request initial status information at instantiation time
- Information persistency

**beckhoffComDevice (C++ class):**

- Initiate connection to PLC
- Connection watchdog functionalities
- Automatic instantiation of s/w devices
- Translation between Beckhoff & Karabo protocols
- Distribution of messages to/from f/w from/to s/w

**PLC + TCP/IP Server + Greeter (f/w):**

- Network I/O
- List of running devices
- Generation of *iAmAliveMessage*

**Firmware Devices (f/w functional block):**

- Controlling and monitoring of hardware equipment

## EPLAN Electric P8 PPE software

- Planning of equipment installation
- Macro programming to streamline:
  - Creation of wiring schemas with automatic
    - check of electrical wiring
    - calculation of length of cables
    - estimation of power consumptions
  - Automatic generation of:
    - documentation
    - bill of material
  - Integration with Beckhoff fieldbus configuration

## Karabo GUI and TwinCAT HMI visualization

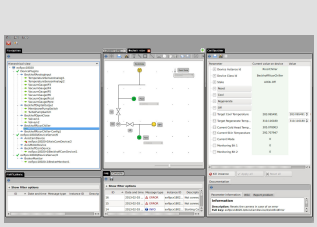
Both offer DIN graphic elements and icons

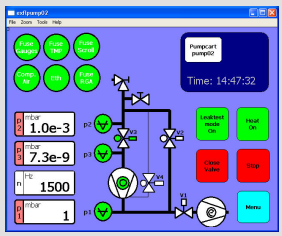
**TwinCAT HMI visualization:**

- Local to the target host
- Specifically tailored and programmed
- Needed in case network connection cannot be guaranteed, mobile target systems (hosts on wheels)

**Karabo GUI**

- Part of homogeneous network distributed system
- Automatically generated and populated



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