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Smart Data for Industrial Control Systems

CERN Technical Workshop

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in collaboration with Siemens AG CT Munich, St. Petersburg, Brasov

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Data Analytics for Industrial Controls

Take advantage of control data

A multitude of Industrial Control Systems

Cooling & Ventilation

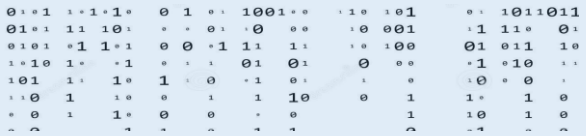
VACUUM

Cryogenics

GAS

Electric Grid

LHC Circuit, QPS, WIC, PIC, …



Storing +100 TB/year

Control Data analytics

Design analytics algorithms

- Expert systems
- Machine learning to deal with heterogeneous control systems

Big Data platform to improve:

- ✓ Control system stability and efficiency
- ✓ Reduce maintenance cost
- ✓ Large scale performances (even physic data quality)
- ✓ Reliability and Safety

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Use cases and Algorithms

- *LHC Circuit Monitoring*
- *Tank leak detection in Cooling and Ventilation*

Online monitoring of the LHC control systems

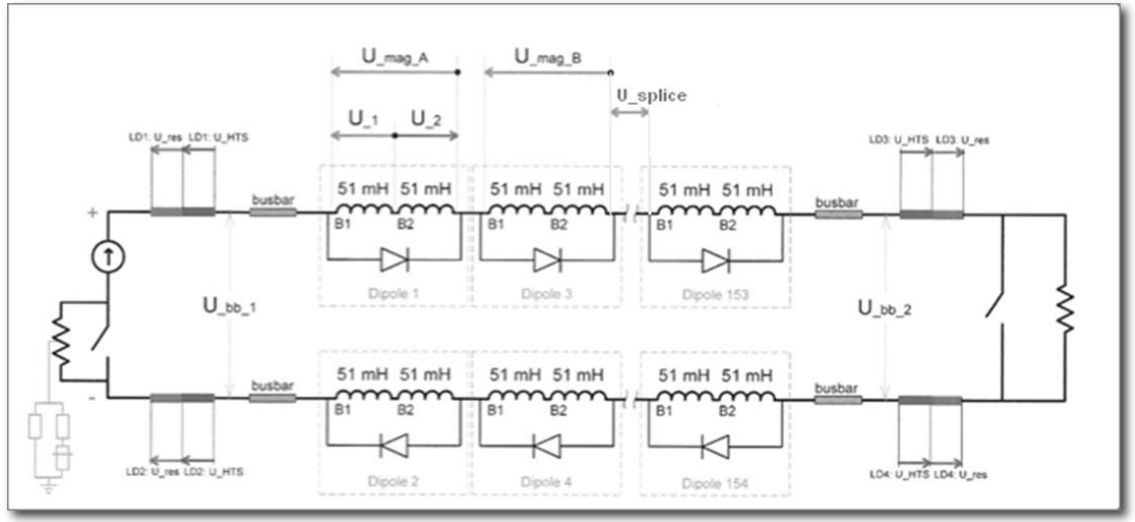
Condition monitoring use-cases

- **LHC Circuit Monitoring**
  - Online analyse the power converter circuits signals and the system status in order to assess their health and detect anomalies
- **Condition Monitoring for Cryogenics**
  - Online analysis of the LHC superconducting magnets pressure, temperature measurements and the openings of their related valves
- **Analysis of control systems alarms based on custom indexes**

LHC circuit monitoring

Condition monitoring analysis *(in collaboration with TE-MPE)*

- **Main Goal: evaluation of the superconducting circuits health**
  - Degradation after 20 years of operations
  - Monitoring conditions: anomalous change of current flows, impedance, circuit functioning …
- **Different analyses:**
  - **Scheduled analysis** depending on the machine cycles, e.g. during the energy ramp, during the energy extraction, etc.
  - **Continuous Analysis** to check the circuits health
  - **Replay of historical data** for qualification and validation
- Electrical circuits:
  - magnets, power converters, switches …
- **Different** working **phases**:
  - anomaly detection
  - ‘energy’ unload and
  - ‘fail-safe



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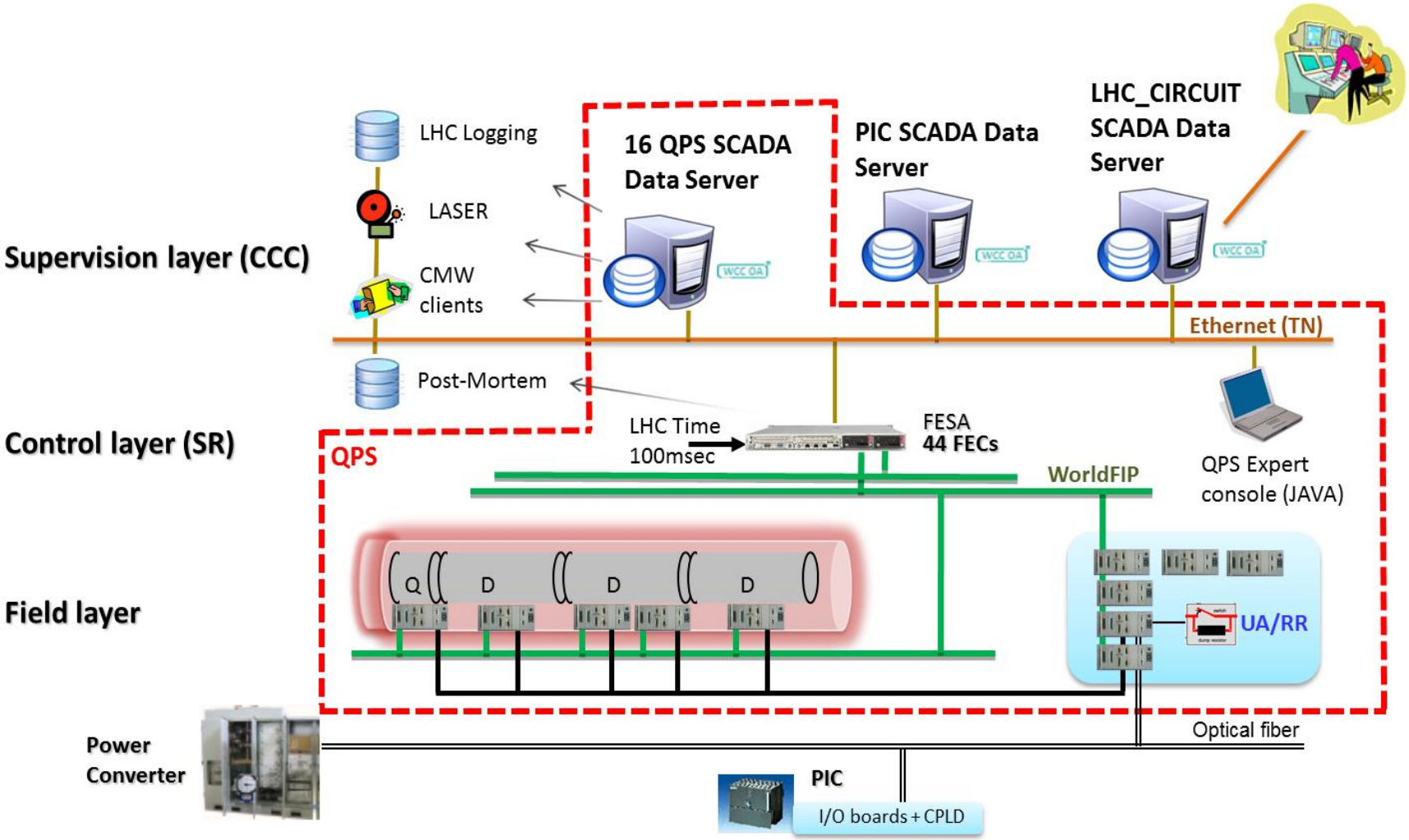
LHC circuit monitoring control infrastructure



Supervision layer:

- WinCC OA
- 16 servers

Control layer:

- 44 industrial FECs
- Readout (from 10KHz to 1Hz)
- RBAC access
- Time sync
- Post-Mortem buffer
- CMW

Field layer:

- 2800 radiation-hard devices
- WorldFIP fieldbus
- Fast readout and protection for magnets and powering circuits
- Signals number: 60 * 4000 QPS + 60 * 2000 FGC systems

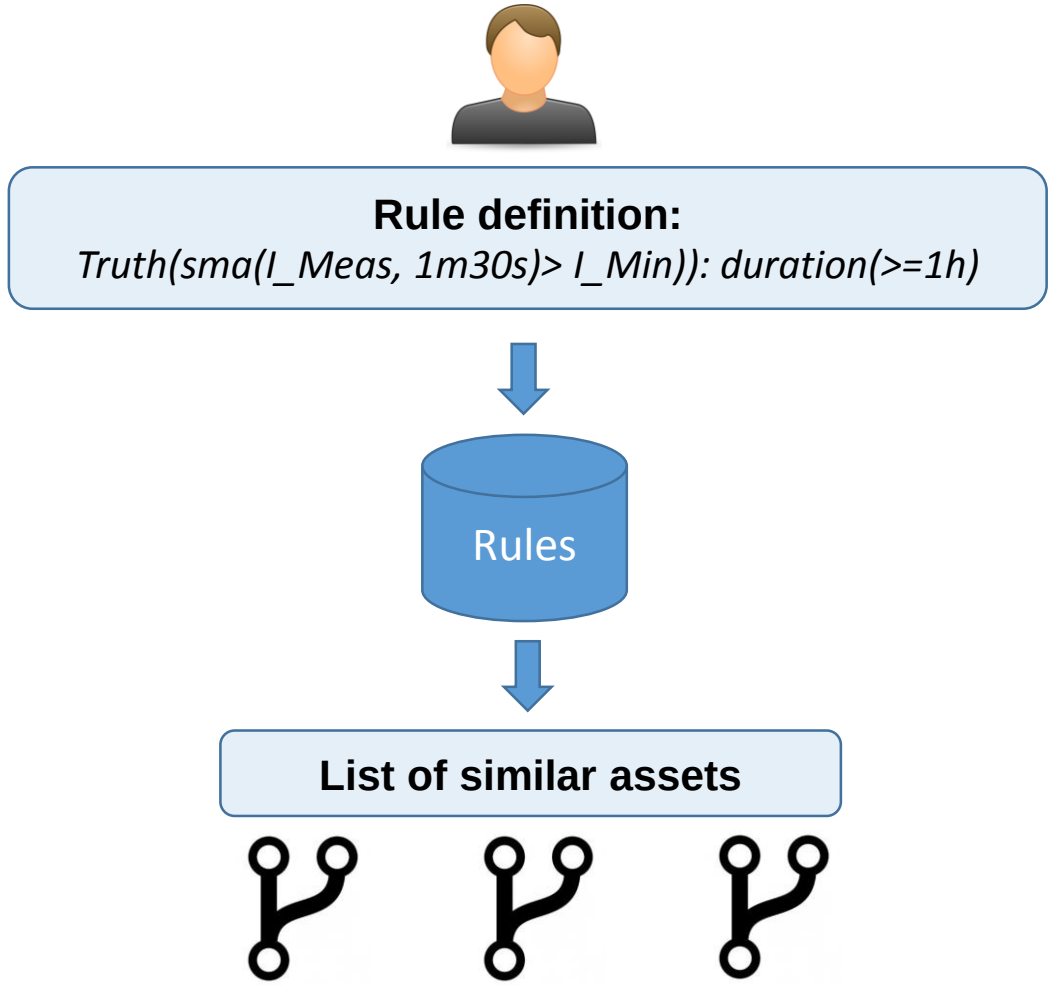
LHC circuit monitoring analysis

Condition monitoring analysis

- Expert system
  - Translate experts' knowledge into formulation sets / rules
  - Asset-based description
  - Rules central storage
  - Rule template to be reused, parametrized, validated

- Signal Processing Language (SPL):
  - Domain specific language (DSL)
  - Simple formulation
  - Time reasoning and temporal expression
  - Mathematical and logical functions
  - Event emitter/ handler
    - Alarms
    - Trigger of rules chain

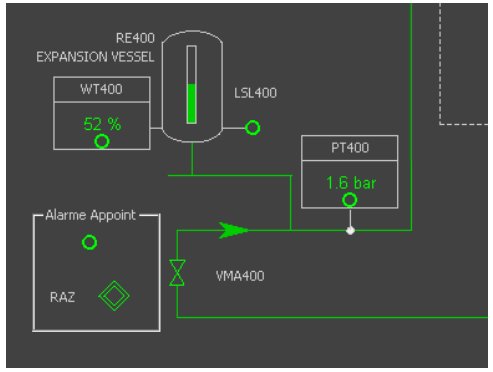
New DSL under implementation: SEPL!

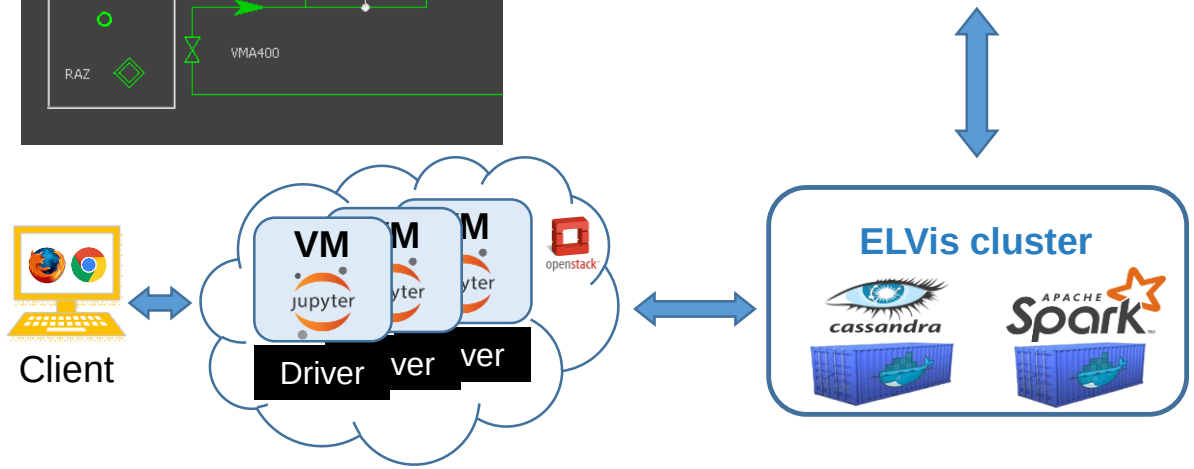


Cooling and ventilation control system

Leak detection in Tanks *(in collaboration with BE-ICS-AP)*

- Anomaly detection based on historical data
- Dual factors analysis:
  - Valve opening time
  - Time between valve openings
- Dynamic control
  - Different alarms thresholds
  - Changing filling conditions





- Detection of “large” leaks:
  - Anomalous valve opening time
- Detection of “small” leaks:
  - Anomalous time interval between valve openings

- Outlier identification based on time distribution of and between valves opening!

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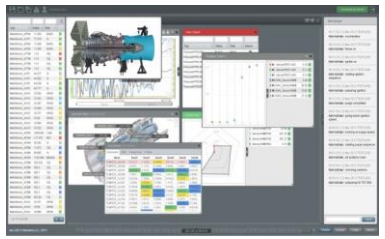
Analytical platforms

- *DCEP and ELVis integration*
- *Industrial IoT support*
- *MindSphere*

Smart Data for Industrial Control Systems

Combining cloud and edge computing into a single framework



ELVis cluster

cassandra

Spark

DCEP Cluster

DCEP Cluster

DCEP Cluster

Analytics master

DCEP Master

Broker

Data Source

Data

UI

Expert systems:

- Manual rules
- ML rules

Rules

Cloud computing

WinCC OPERA OA

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Middleware

VM

jupyter

Driver

openstack

Client

Cloud & Edge Link

Fieldbus

DCEP Cluster

DCEP Cluster

Analytics worker

Analytics worker

DCEP Cluster

Broker

Data Source

Data

Edge computing

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Industrial IoT islands

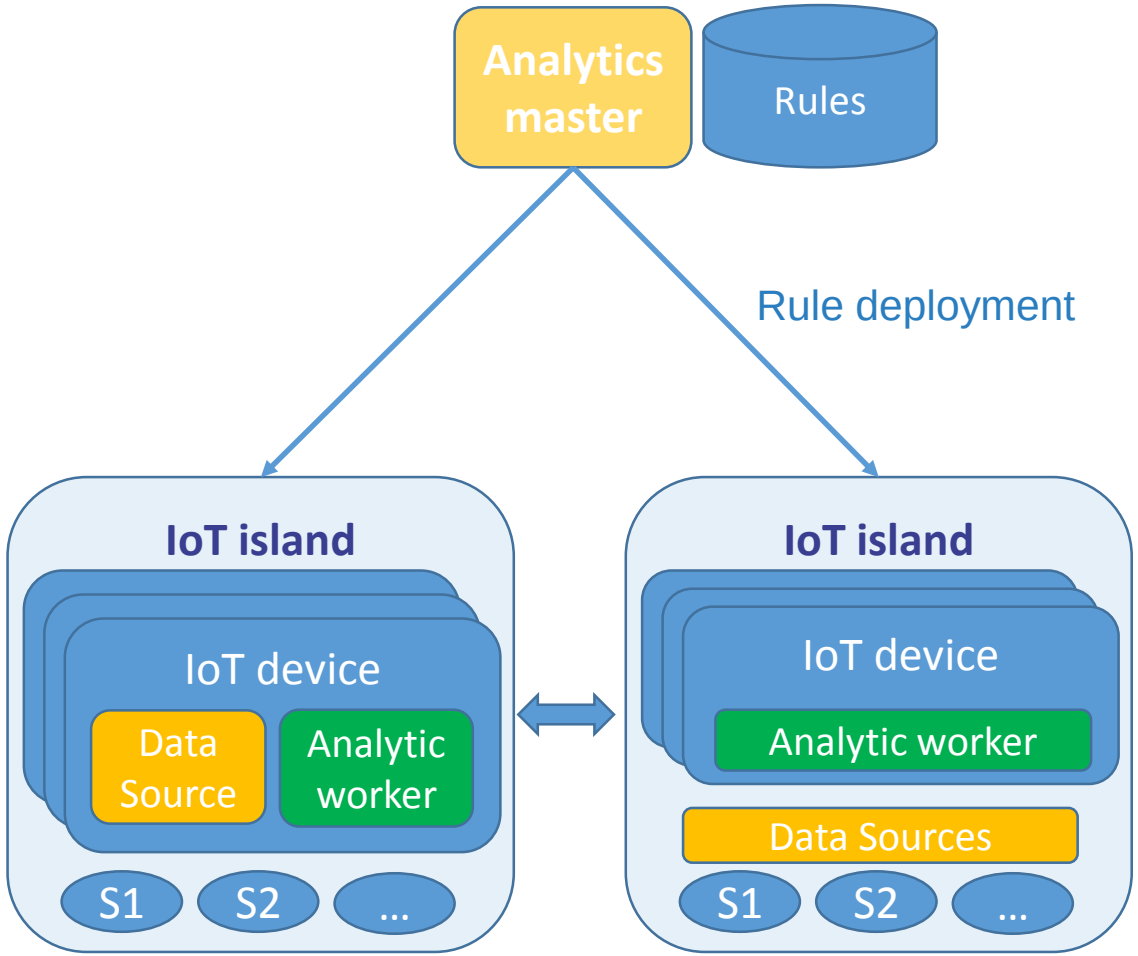
Fully autonomous DCEP cluster that can interoperate with other IIoT islands

- Industrial IoT analytical **benefits**:
  - Shorter latency for online analysis
  - Reduced network load
  - Industrial modelling/segmentation
  - Increased reliability
- Siemens involvement:
  - **New collaboration** with an IIoT group
  - Existing collaboration with the cloud computing group
- **Multi-platform** support
  - Raspberry Pi, Siemens IoT 2020/2040, …

DCEP Industrial IoT islands

IOT support in the analytical framework

- **Dynamic device registration**
  - Compatible with the control system structure
  - Sensors description
  - Available resources
  - Dynamic configuration
- **Service discovery**
  - Services endpoints
  - Permitted operations
  - Event subscription
  - Dynamic update due to device mobility
- **Data ingestion**:
  - From **field devices** and SCADA
  - **Multi-protocol** support
  - Time **synchronization**
  - **Reduced impact** on Industrial Controls
    - Network load across the nodes/SCADA
    - Not invasive fieldbus communication



MindSphere

Cloud-based Platform as a Service (PaaS) provided by Siemens

- Evaluating analytical modules:
  - Sensors validation
  - Anomaly detection in sensors measurements
  - Control process assessment and availability
  - Condition monitoring system based on KPIs
- Integration with CERN control systems
  - Web services to upload and run analytical modules
  - Open API
- Migration of CERN analytical algorithm to MindSphere
  - Implementation of the PID evaluation in the Siemens web service domain

Summary

- Different CERN use-cases
  - Expert systems for LHC circuit monitoring and anomaly detection in CV
- New analytical platform for both cloud and edge computing
  - Deployment and integration with CERN control systems
- SEPL to support for numerical and text analysis
- MindSphere
  - Cloud-based Platform as a Service (PaaS) provided by Siemens

2017 data analytics publications in international conferences:

- *An expert knowledge based methodology for online detection of signal oscillations – CIVEMSA 2017, F. Tilaro, M. Gonzalez, B. Bradu, M. Roshchin*
- *Model Learning Algorithms for Faulty Sensors Detection in CERN Control Systems - ICALEPCS 2017, F. Tilaro, B. Bradu, F. Varela, M. Roshchin*
- *Automatic PID Performance Monitoring Applied to LHC Cryogenics - ICALEPCS 2017, B. Bradu, E. Blanco, F. Tilaro, R. Marti*
- *Data Analytics Reporting Tool for CERN SCADA Systems - ICALEPCS 2017, P. J. Seweryn, M. Gonzalez-Berges, J. B. Schofield, F. M. Tilaro*

Thank you!

CERN BE-ICS

https://be-dep-ics.web.cern.ch/