FULL STACK PLC TO EPICS INTEGRATION AT ESS

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(on behalf of the ICS Automation Section)

ICALEPCS 2023 – PLC Workshop

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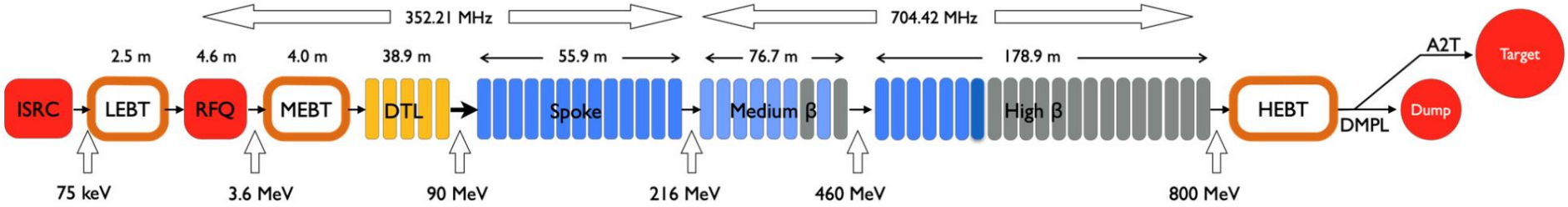
ESS – ICS Automation Section

- The European Spallation Source is currently under construction in Lund, Sweden
  - Even if the beam power was reduced to 2MW, the facility is still expected to be world leading shortly after it becomes operational, the first beam on target is expect for 2025!

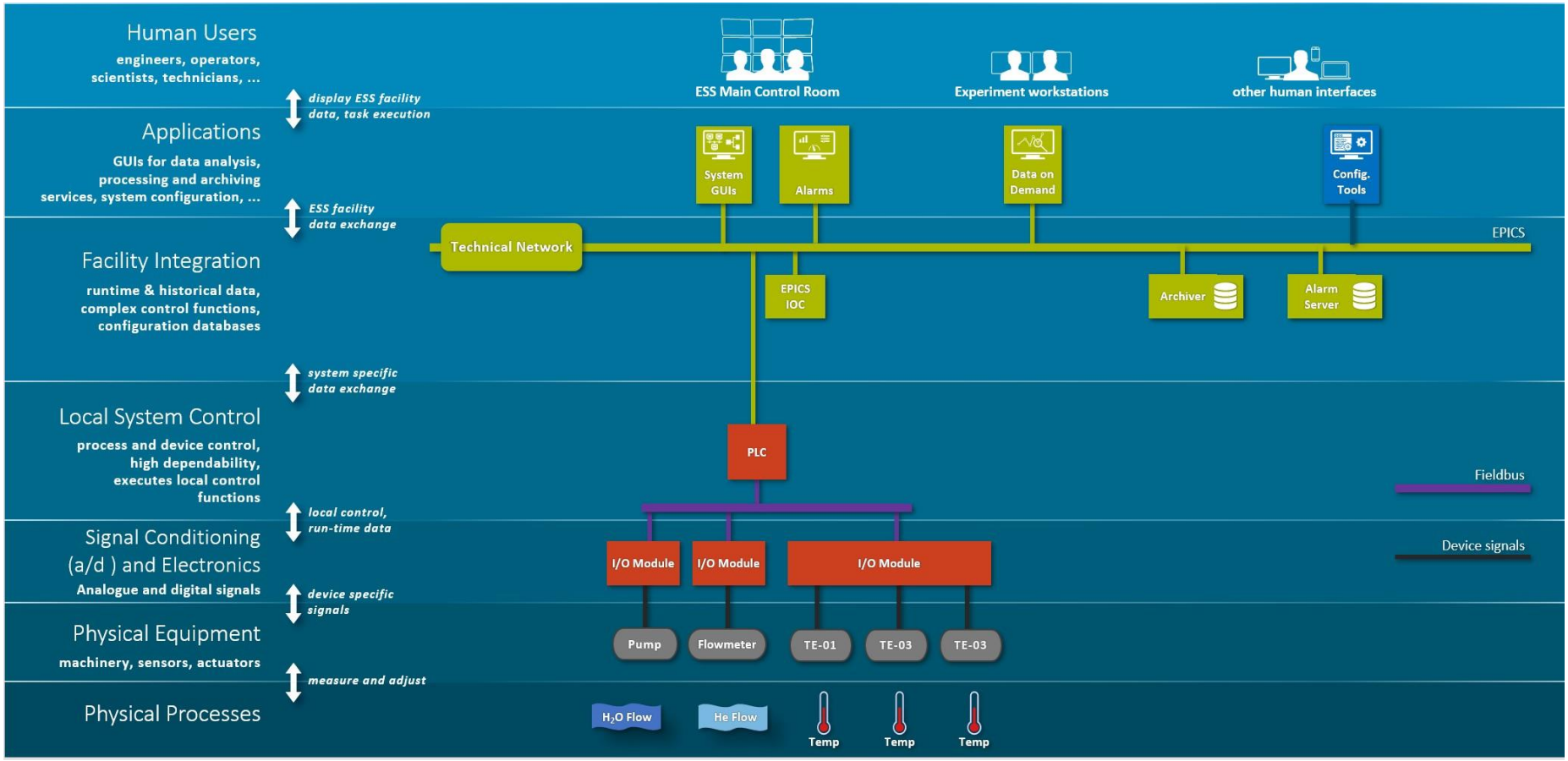


ICS Automation Section

- The Automation Section is composed by around 20 Automation Engineers, among ESS employees and consultants
- ICS Automation Section, coordinates the design, development, maintenance, test and EPICS integration (IOC/OPI) of Basic PLC-based Control Systems
- Grouped into different Work Packages for LINAC, Target, Conventional Facilities, Neutron Instruments

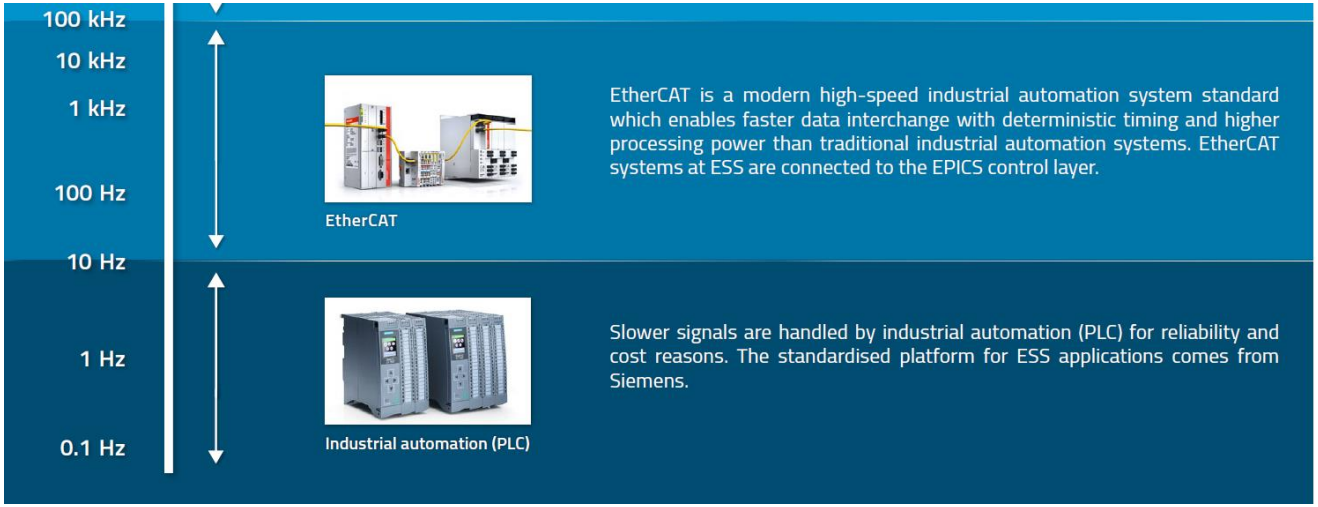
Generic Layer Architecture of a PLC-based Control System at ESS

EUROPEAN SPALLATION SOURCE



PLC Hardware

- PLC industry standard systems has been chosen based on the required signal speed:
  - for mid-range performance (< 100 kHz) Beckhoff/EtherCAT has been chosen to implement real time fieldbus applications (e.g. motion control systems)
  - to handle slower signal (< 10 Hz), the equipment selected was Siemens



PLC Engineer Workstartions

- TIA Portal is used for programming, developing, and configuring Siemens PLCs, HMIs, and frequency inverters.
  - Currently all the PLC projects are gradually upgraded from version 15.1 to version 17; the possibility to support version 18 with our current control ecosystem is also under investigation.
  - All the Siemens licenses are stored in a centralized server in a internal DMZ network, which is part of the ESS Technical Network Zone (TN).
- TwinCAT 3 from Beckhoff Automation turns almost any compatible PC into a real-time controller with a multi-PLC system, NC axis control, programming environment and operating station.

Tools

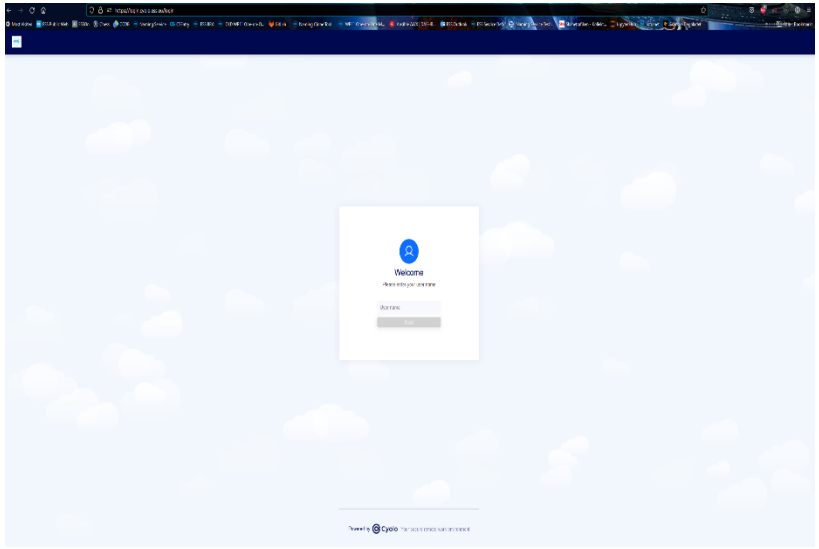
- Versiondog is a version control and archiving tool to maintain PLC projects (mainly Siemens)
  - Users can install versiondog client in their own laptop to access the server.
  - PSG Group use a dedicated versiondog server for PLC Safety control systems
- GitLab, is also used for archiving and versioning some Beckhoff/TwinCAT PLC projects, being a valid alternative to versiondog.

Development & Deployment VMs

- Two clusters of Windows (Windows 10 E LTSB) VMs with the same configuration and needed software were setup
- One cluster to deploy projects to PLCs which are connected to the ESS Technical Network for production,
- Another one, which is connected to the ICS Lab Network, for development and deployment for PLC testing purposes.
- Both clusters can access the Siemens license server, as well as the Control Management Ecosystem services and tools

Cyolo (https://cyolo.io/)

- In order to give access to the users in a safe and controlled way to the VMs connected to the TN, the Cyolo remote access solution has been configured



Cyolo

- The remote access application portal provides the capability to the users to connect to applications (e.g. the
- VMs) based on their native protocols (e.g. RDP) or using the web user interface.
- Users can access the Siemens License Server from their own laptop connected to the office network (or home via VPN) using the Cyolo App, do for instance local PLC project development

Control Management Ecosystem

- The Control Management Ecosystem has been built to facilitate management and maintenance of integrated control systems.
- The ecosystem is composed of a number of different services and complimentary tools

Naming Service and pvValidator

- The ESS Naming convention applies to systems and devices and signals controlled and monitored using EPICS.
- Once valid ESS names have been identified, a set of “Property” can be attached to them, in order to form a valid EPICS records name (aka PVs) according to predefined format and rules, for instance *ESSName*:*Property*

  (e.g. DTL-010:EMR-TT-001:Temperature)

Naming Service and pvValidator (cont'd)

- The web-based "Naming Service" is therefore provided by ICS division to assist users of the ESS naming convention to register ESS Name, and the ESS Naming Coordinators to administer their name elements
- pvValidator is python script was made in order to help control system integrators to validate PVs according to ESS naming convention, either online from running IOC, or offline via some text input file (either a PV list or an EPICS DB)

EUROPEAN SPALLATION SOURCE

Naming Service

Issues | Contact Support | evanfoy

Home | ESS Name Registry | System Structure | Device Structure | Help

View | Filter | Columns | Filter status: | Actions

System	Subsystem	Discipline	Device Type	ESS Name	Description
A2T	010PRL	RFS	PRLTap	A2T-010PRL:RFS-PRLTap-054	
A2T	010Row	CnPw	U	A2T-010Row:CnPw-U-001	Cabinet 01 in rack row 01 of the
A2T	010Row	CnPw	U	A2T-010Row:CnPw-U-002	Cabinet 02 in rack row 01 of the
A2T	010Row	CnPw	U	A2T-010Row:CnPw-U-003	Cabinet 03 in rack row 01 of the
A2T	010Row	CnPw	U	A2T-010Row:CnPw-U-004	PBI Control rack (BCM-07, BPM-
A2T	010Row	CnPw	U	A2T-010Row:CnPw-U-005	PBI Control rack (ICBLM-15, ICB
A2T	010Row	CnPw	U	A2T-010Row:CnPw-U-006	PBI Control rack (FPM-03, WS-0
A2T	010Row	CnPw	U	A2T-010Row:CnPw-U-007	PBI Control rack (APTM-01, APT
A2T	010Row	CnPw	U	A2T-010Row:CnPw-U-008	Cabinet 08 in rack row 01 of the
A2T	010Row	CnPw	U	A2T-010Row:CnPw-U-009	Cabinet 09 in rack row 01 of the
A2T	010Row	CnPw	U	A2T-010Row:CnPw-U-010	Cabinet 10 in rack row 01 of the
A2T	010Row	CnPw	U	A2T-010Row:CnPw-U-011	Cabinet 11 in rack row 01 of the
A2T	010Row	CnPw	X	A2T-010Row:CnPw-X-001	Electrical Socket - Cooler SHX3(
A2T	010Row	CnPw	X	A2T-010Row:CnPw-X-002	Electrical Socket - Cooler SHX3(
A2T	010Row	Ctrl	CPU	A2T-010Row:Ctrl-CPU-100	Beckhoff PC for Gamma Blocker
A2T	010Row	C			
A2T	010Row	C			
A2T	010Row	C			
A2T	010Row	C			
A2T	010Row	C			
A2T	010Row	C			
A2T	010Row	M			

pvValidator 1.3.1
(c) ESS - 2021

Press F1 for Help

Legend:
******: Skip Naming API Validation Check
------: Not Registered/Wrong Format

Curr Row/Col: (1,1) Tot Rows/Cols: (29, 8)

System	Subsystem	Discipline	Device	Index	Property	PV Name	Validation Comment
------	------	------	------	------	------	gnappo:dis-dev-idx:#PumpStatus	NOT VALID (Name Fail)
------	------	------	------	------	------	gnappo:PiraniGauge_THR	NOT VALID (Wrong Format)
------	------	------	------	------	------	gnappo:gnappo12345678901234	NOT VALID (Wrong Format)
------	------	------	------	------	------	gnappoalias	NOT VALID (Wrong Format)
------	------	------	------	------	------	g	NOT VALID (Wrong Format)
------	------	------	------	------	------	gnappoalias2	NOT VALID (Wrong Format)
------	------	------	------	------	------	gnappo::1PiraniGauge_RB	NOT VALID (Name and Rule Fail)
------	------	------	------	------	------	gnappo::PiraniGauge_SP	NOT VALID (Name Fail)
------	------	------	------	------	------	gnappo::AliasSetpoint	NOT VALID (Name Fail)
------	------	------	------	------	------	gnappo::PiraniGauge_LN	NOT VALID (Name Fail)
------	------	------	------	------	------	gnappo::Sim	NOT VALID (Name and Rule Fail)
------	------	------	------	------	------	gnappo::Pwr	NOT VALID (Name Fail)
------	------	------	------	------	------	gnappo::SimulationMode	NOT VALID (Name Fail)
------	------	------	------	------	------	gnappo::MyPrOp	NOT VALID (Name and Rule Fail)
------	------	------	------	------	------	gnappo::myprop	NOT VALID (Name and Rule Fail)
------	------	------	------	------	------	gnappo::MyPr0p	NOT VALID (Name and Rule Fail)
------	------	------	------	------	------	gnappo-sto::GigioGigiabcdefghilm-S	NOT VALID (Name Fail)
------	------	------	------	------	------	gnappo-sto::Supercalifragilisticheshpiralidoso$	NOT VALID (Name and Rule Fail)

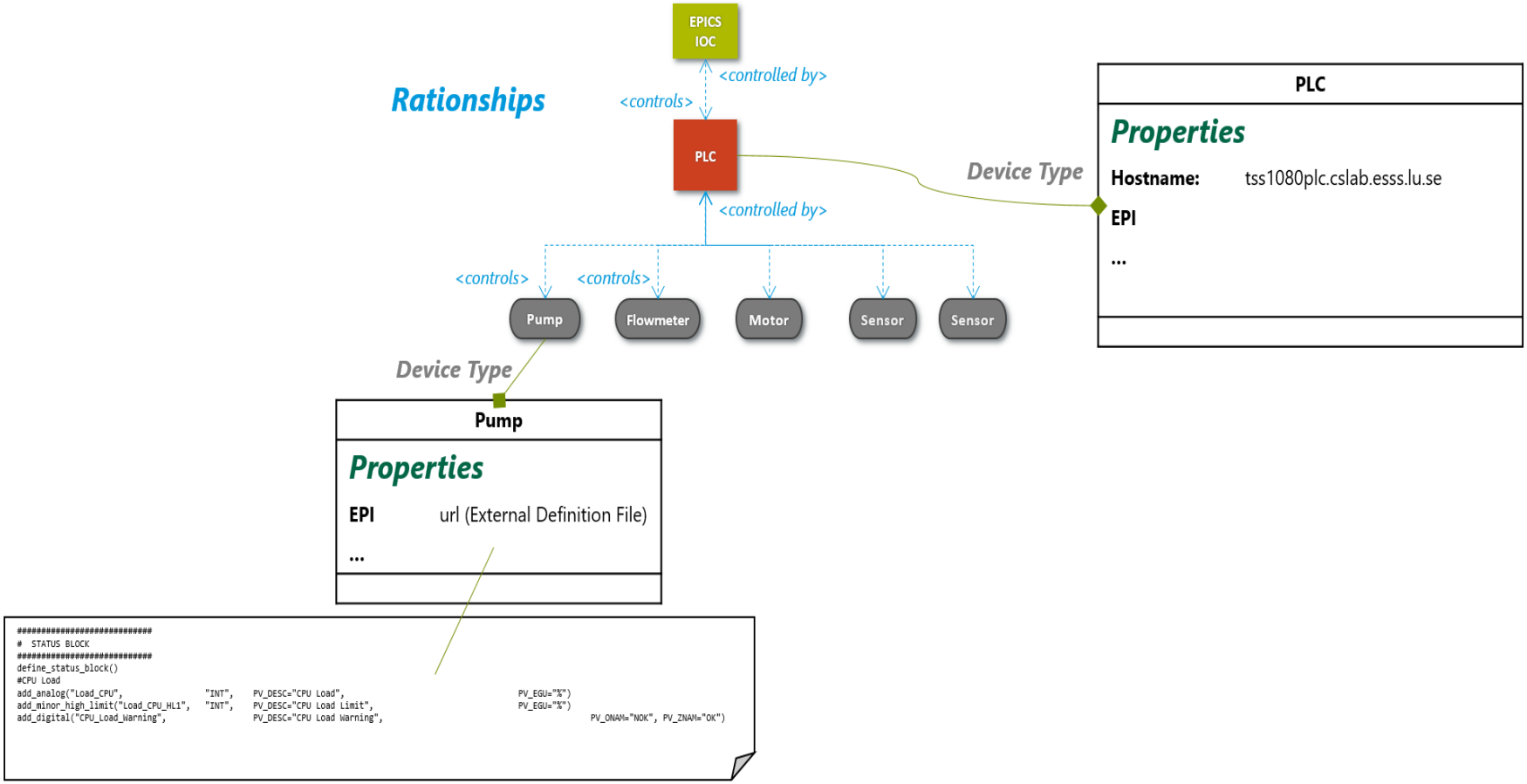
```
PV Summary --> gnappo:dis-dev-idx:#PumpStatus

Info: The PV follows ESS Name Format
Info: The PV is an "Internal PV"
Info: The PV follows ESS PV Property Rules
Error: the System "gnappo" does not exist in the Naming Service
Error: the Discipline "dis" does not exist in the Naming Service
Error: the Device "dev" does not exist in the Naming Service
```

CCDB

- The Controls Configuration Data Base (CCDB) contains configuration information relevant for controlling physical and logical devices such as cameras, power supplies, pumps, valves, etc.
- This information is aggregated in the CCDB in one model of the ESS. The information in this model is complemented by supporting software products such as the ESS Naming Service for unique identification of devices

Modelling of PLC-Based Control Systems



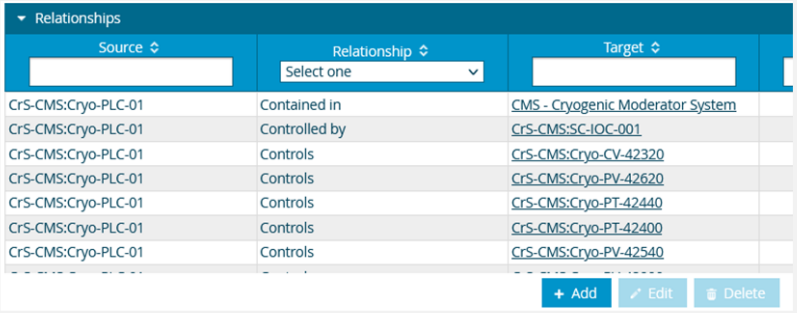
PLCFactory

- It is a python-based software tool that is used to generate the set of codes necessary to achieve integration between a PLC and EPICS.
- PLCFactory is intended to simplify programming PLCs and creating the communication interface between EPICS and PLCs
- PLCFactory can generation alarm and archiver file configurations, and the code to provide diagnostic information on the status of the communication between IOC and PLC.

PLCFactory Workflow

Input

- The PLC system is modelled in CCDB:



- The interface definition ("properties") can be defined in a ".def" file for each device type, and referenced in CCDB.

```
add_analog("MF_MV","REAL", PV_DESC="Mass Flow Measured Value", PV_EGU="kg/s")
add_analog("MF_SP","REAL", PV_DESC=" Mass Flow SetPoint", PV_EGU=" kg/s ")
add_digital("Open", PV_DESC="Valve fully open")
add_digital("Closed", PV_DESC="Valve fully closed")
```

Note that all records in CCDB (i.e. "slots") are dynamically linked to the ESS Naming Service; therefore the device names in CCDB are equal to the names defined in the ESS Naming Database.

PLC Factory

- Python script:
  - gets the PLC interface definition from CCDB (from function call argument)
  - iterates through the list of controlled devices
  - compiles a .db file (EPICS IOC) and variables declaration file (for the PLC code compilation)

Output

- IOC files:
  - **PLC Factory can produce the complete IOC!**
- PLC files:
  - **Modbus & S7 comm** message definition.
  - Pre-defined variable list for the PLC project

Other advantages

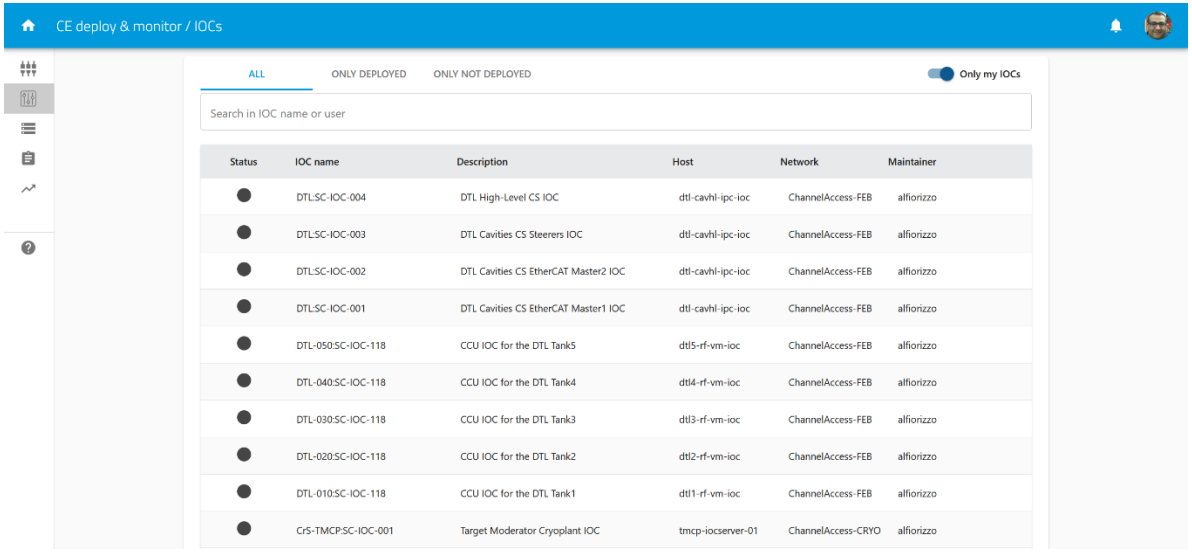
- PV names are inherently valid
- The model in CCDB is the *actual design*.

Disadvantages

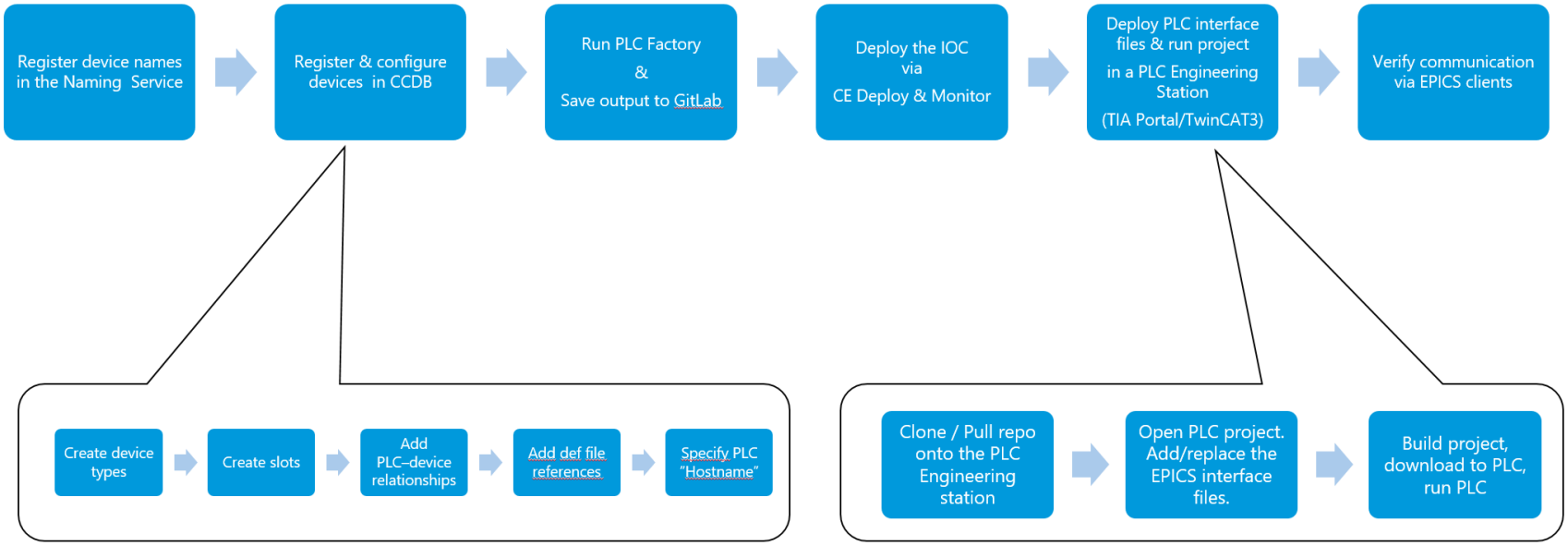
- Requires manual deployment of files to the PLC project + mapping for every update.
- Limited signal exchange rate, typically set to poll at 100ms-200ms.

CE Deploy & Monitor tool

- A deployment tool that installs and manages the runtime of IOCs on a host machine.
- It also provides IOC configuration control and history, allowing for easy troubleshooting and the ability to revert to previous versions if necessary



PLC-to-IOC Overview Workflow



Future Upgrades: Control Management Ecosystem

- CCDB was originally designed to be a “database of everything”, which is ill-suited for storing types of devices and relationships between them.
  - The goal is to properly integrate this into our standard IOC deployment toolchain (CE Deploy & Monitor) including PLC-based IOCs having a much simplified data format.
- :

Future Upgrades: PLC-EPICS Communication Protocol

- One current limitation in PLCFactory is the PLC-EPICS communication protocol available at the moment is TCP/IP (step7 and modbus).
- This can be fine for Siemens PLCs, however for some Beckhoff/TwinCAT projects (e.g. motion control project) the communication speed cannot be obviously satisfying.
- For these projects, whose number of PVs is quite contained, the integration using the fast Beckhoff ADS protocol is done manually (it should be possibile to include the ADS protocol inside PLCFactory)
- One other solution that is currently under investigation is the use of OPC UA, which can be used both for Siemens and Beckhoff PLCs.
- The use of only one protocol could be then an advantage in term of maintenance, moreover the OPC UA EPICS module is maintained by the EPICS community.
- Benchmarks tests both in Beckhoff and Siemens PLCs are currently under investigation.
- A final decision will be taken based upon the outcome of those tests, adding also into account the cost of the relative OPC UA license for both PLC systems.

Future Upgrades

- Develop a better unit test for PLC-based control systems using pytest
- Beckhoff offers also an alternative operating system, TwinCAT/BSD, for selected Beckhoff Industrial PC platforms.
  - TwinCAT/BSD combines the TwinCAT runtime with FreeBSD
  - Being FreeBSD a UNIX like environment, it would be possible to run EPICS IOCs locally, avoiding the overhead of a VM
  - See K. Lauer poster: “TwinCAT BSD Virtual Machines and Ansible Provisioning”

Acknowledgement

- Thanks to the many colleagues at ESS and in particular the ICS division, the Controls Infrastructure Group and the Motion Control & Automation Group.

END

- QUESTIONS ?