Towards Asynchronous Programming on Tango

An asyncua Device Server for OPC UA

Emilio Morales - 09.06.2026

Overview

- Introduction
- ALBA Equipment Protection System
- Technologies involved
- Implementation and benchmarks
- Testing outside ALBA
- Conclusions

Introduction

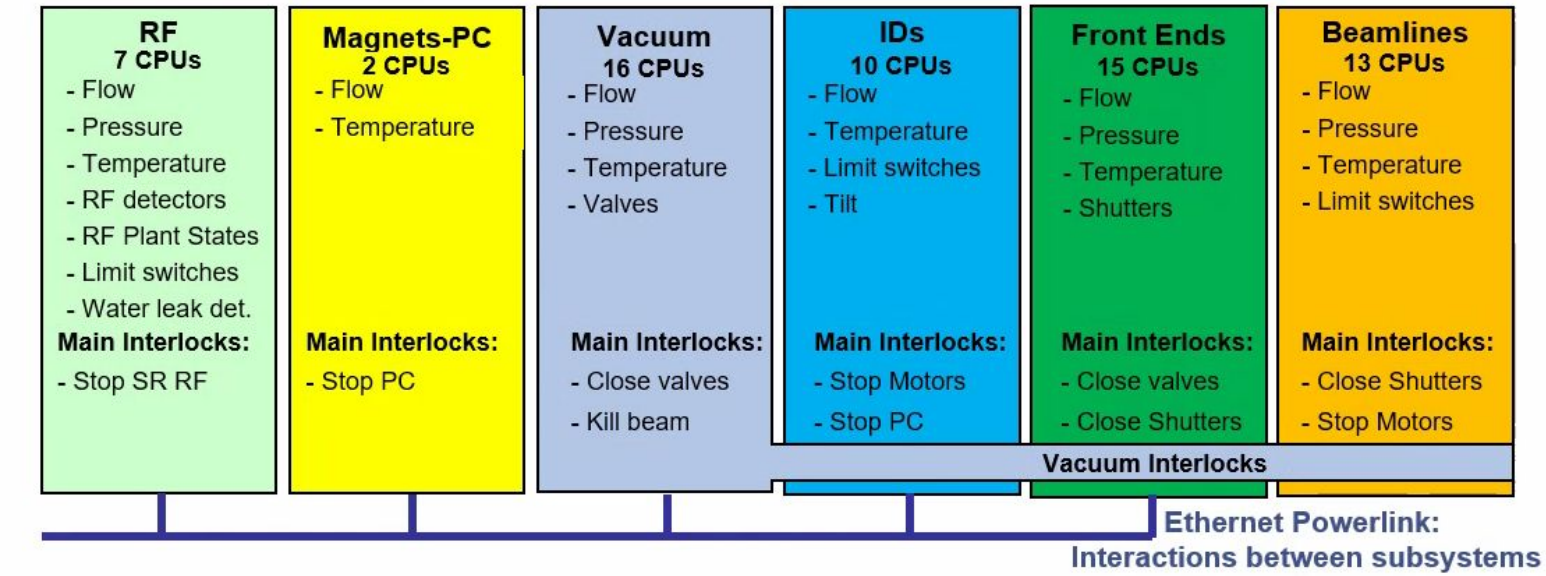
- ALBA II demands scalable and maintainable control system solutions.
- We need to review and enable modern technologies for the future facility.
- OPC UA give us the opportunity to face new challenges.
- Tango ecosystem help us to perform this challenges.

Introduction

- Not the first OPC UA solution.
- MAXIV, SOLARIS and SOLEIL have their own OPC UA solutions.
- There is another solution inside Tango Clases Catalog (NEXEYA).
- We want to explore the capabilities of PyTango GreenModes.
- Thank you for the help and support!

ALBA Equipment Protection System

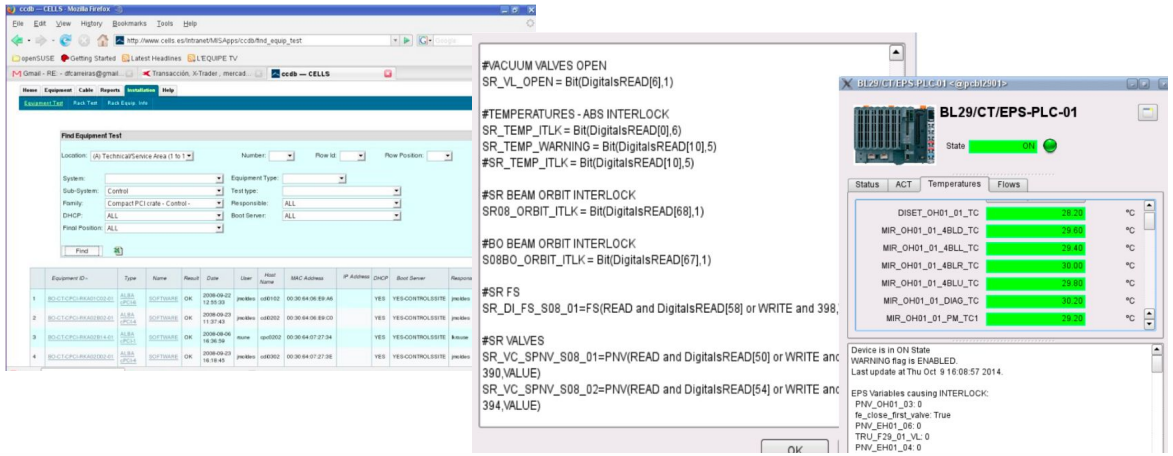
- 6 different subsystems
- 63 PLC CPUs
- ~ 400 nodes - 1500 parameters
- Powerlink Architecture
- Interlock machine in 50 ms
- 50 PLC in main Powerlink network

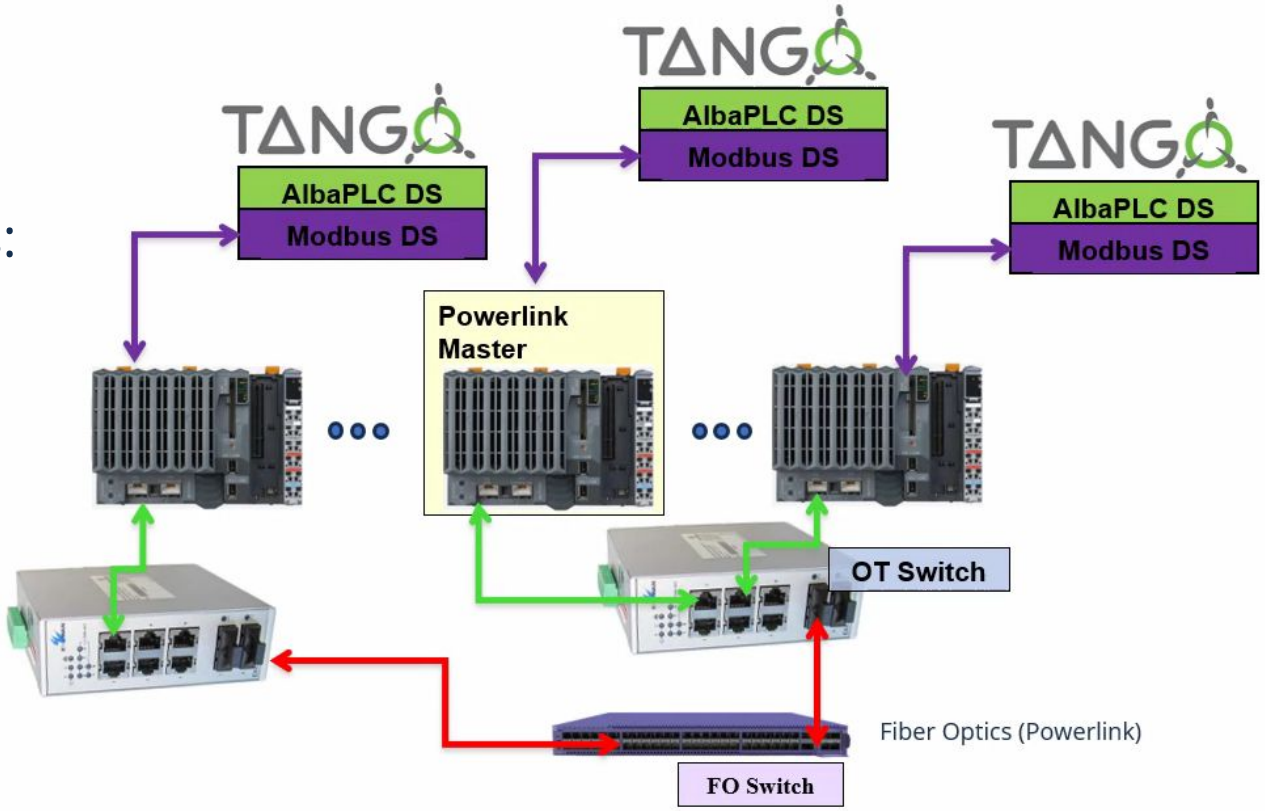


Current EPS System

1. Cabling database ⟷ Autogeneration
2. CSV file: Modbus ⟷ Variable mapping
3. EPS_LIBRARY: 16 bit Status Words
4. Modbus TCP communication
5. Integration with Tango using 2 devices:

   PyPLC (generic) & **AlbaPLC** (specific).





ALBA

TANGO

Modbus TCP

Open and widely adopted industrial protocol, valued for its simplicity and broad compatibility, but limited when used at large scale or in modern demanding systems.

Strengths

- *Simplicity*: Lightweight client–server protocol.
- *Compatibility*: Open standard, supported by most PLCs and SCADA systems.
- *Ethernet Integration*: Runs on TCP/IP, reusing existing infrastructure.

Weaknesses

- *Limited Data Model*: 16-bit registers, no explicit data typing or semantics.
- *No Native Security*: Lacks encryption, authentication and data address validation.
- *Scalability*: Polling-based, limited concurrent connections and increasing latency at large scale.

OPC UA

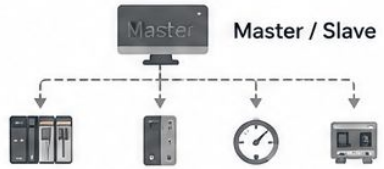
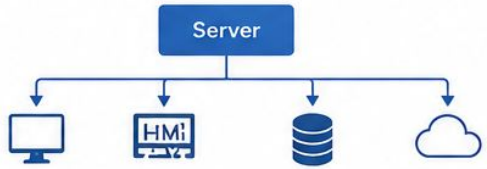
A secure, event-driven standard for industrial systems that enables scalability and advanced data modelling, but achieving performance requires careful setup and tuning, depending on the PLC CPU model.

Strengths

- *Interoperability*: Connects devices from different vendors, simplifying integration.
- *Robust Security*: Built-in encryption, authentication, authorization, and digital signatures.
- *Self-Descriptive & Scalable*: Exports PLC data structures directly and supports client–server and PubSub models for flexible deployments.

Weaknesses

- *Implementation Complexity*: Careful setup and specialized knowledge.
- *Concurrency Challenges*: Asynchronous operation may lead to race conditions.
- *Subscription Limits*: Hard limits depending on vendor, constraints on update rates and number of nodes.

MODBUS Simple & Traditional		OPC UA Advanced & Future-Readv
 Master / Slave	ARCHITECTURE	
Flat data (coils, registers) 	DATA MODEL	 Rich, structured information model
 No security by standard	SECURITY	 Built-in security (encryption, auth, authorization)
 Vendor specific implementations	INTERPERABILITY	 Vendor independent & highly interoperable
 Limited (small systems)	SCALABILITY	 High (large, complex systems)
Read / Write 	FUNCTIONALITY	 Events & Alarms  Historical Data  Subscriptions  Discovery
 Legacy systems Simple devices Cost-sensitive	USE CASES	   Modern systems IIoT & Industry 4.0 Integration & digitalization
 Good for simple communication needs		 Ready for the future of industrial communication

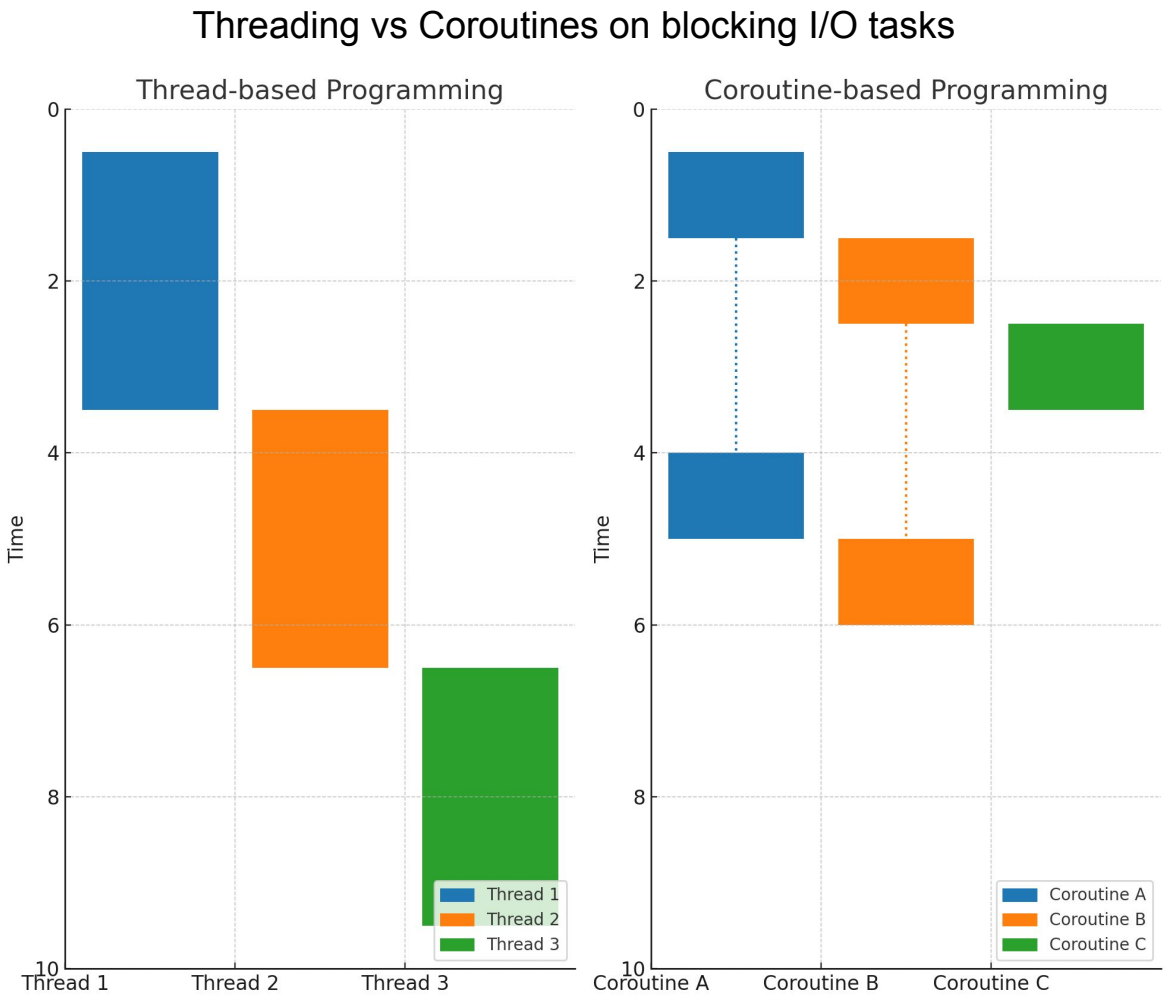
Asynchronous programming

Synchronous / Single-threaded

- Code waits for each task to finish: easy to debug, inefficient for I/O-bound tasks
- When using multiple threads or processes, increasing complexity and resources.

Asynchronous / Coroutine-based

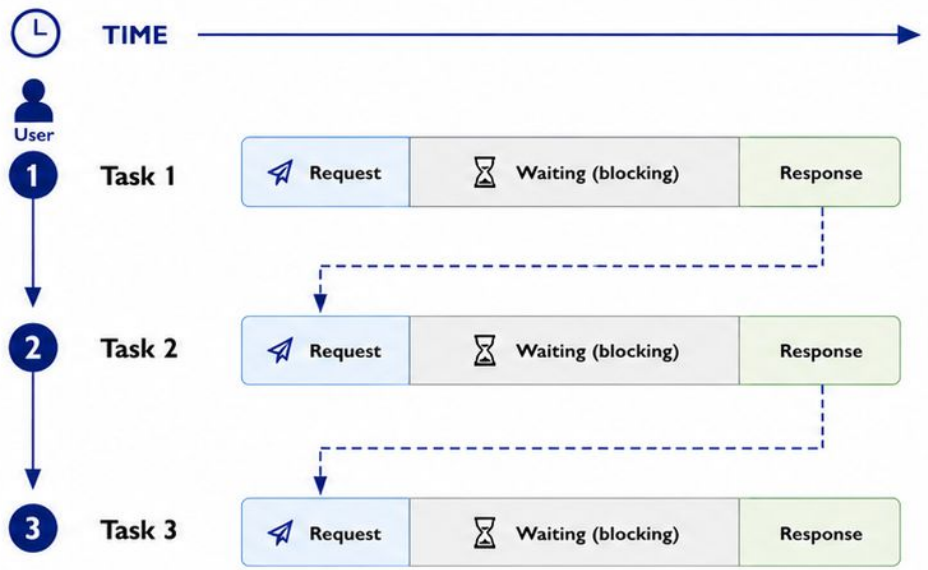
- Allows multiple tasks (coroutines) to progress concurrently without blocking
- Lightweight frameworks
- Useful for certain applications : Networking, High-latency, Event-driven.



SYNCHRONOUS vs ASYNCHRONOUS

SYNCHRONOUS (BLOCKING)

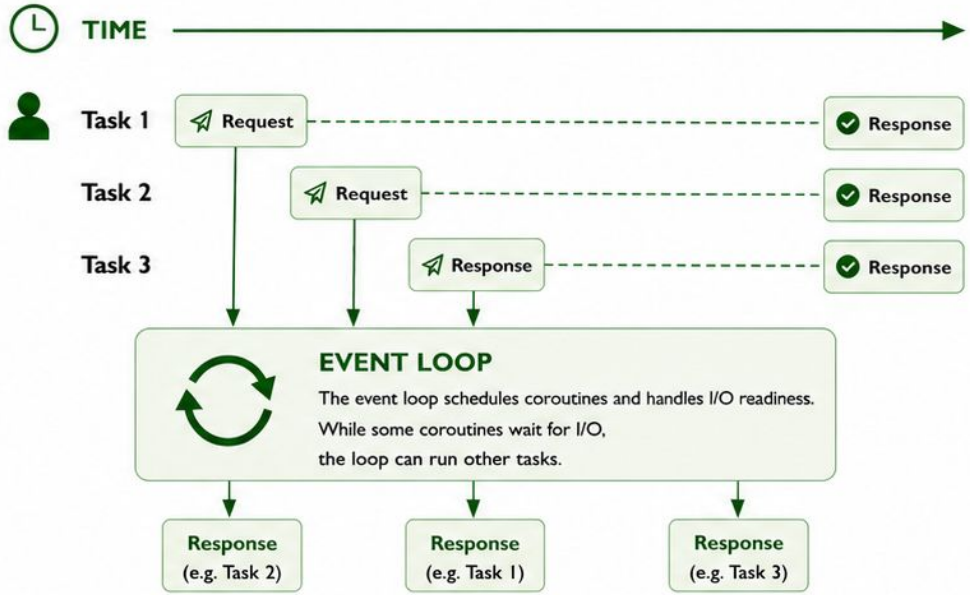
One task at a time.
Next task starts only after previous one completes.



- Sequential execution
- Blocking waits
- Next task starts after previous completion
- Simple model, but limited scalability for I/O-bound workloads

ASYNCHRONOUS (ASYNCIO – EVENT LOOP + COROUTINES)

Tasks start and make progress without waiting for others.
Multiple I/O operations can be in flight at the same time.



- Non-blocking I/O
- Coroutines scheduled by an event loop
- Multiple I/O operations in flight
- Efficient and scalable for I/O-bound workloads

Asynchronous execution can be achieved using **threads** or using **coroutines** with an event loop.
Both approaches are valid and well-suited for **I/O-bound problems**.
At large scale, **event loops with coroutines** are often the better choice due to lower overhead and higher scalability.
In our case, we use **asyncio** (event loop + coroutines) inside **Tango Green Modes**.

asyncio & asyncua

asyncio

Python native library for asynchronous programming.

Pros

- *Efficiency*: Reduces idle time in I/O-bound.
- *Scalability*: Thousands of concurrent connections with low overhead.

Cons

- *Complexity*: Learning async/await patterns and event loop concepts.
- *Debugging*: Concurrency issues (race conditions, deadlocks) are hard to trace.

asyncua

Open-source Python library for implementing OPC UA clients and servers.

Features

- Support for core OPC UA functionalities.
- Asynchronous design ideal for large subscriptions and high-frequency updates.
- Seamless integration with modern Python applications.

FreeOpcUA Project:
https://github.com/FreeOpcUa/opcua-asyncio

TANGO, PyTango and Green Modes

PyTango

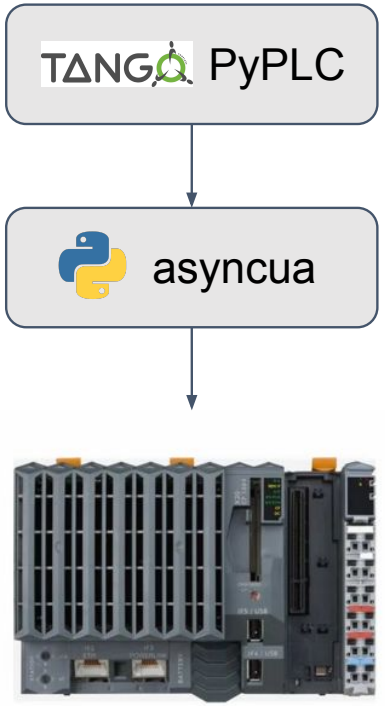
- Tango Python binding to enable rapid development of device servers and client applications.
- Widely adopted across the Tango community.
- **www.tango-controls.org**

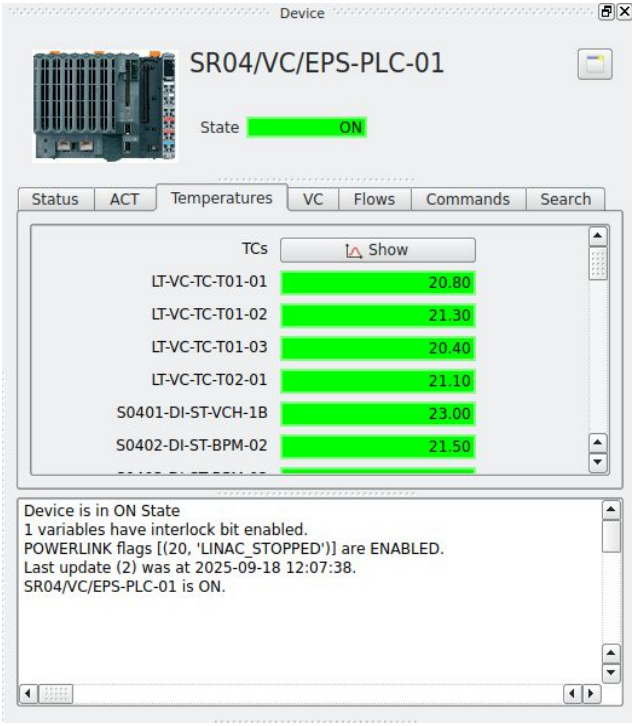
Green Modes

- This enables asynchronous Python frameworks in Tango (**asyncio**, **gevent**).
- Avoids explicit thread management:
  - Lower overhead
  - Simpler code
  - Improved scalability
- Effective for I/O-bound operations and client applications refresh.

PyPLCua- Generic OPC UA Comms. Layer

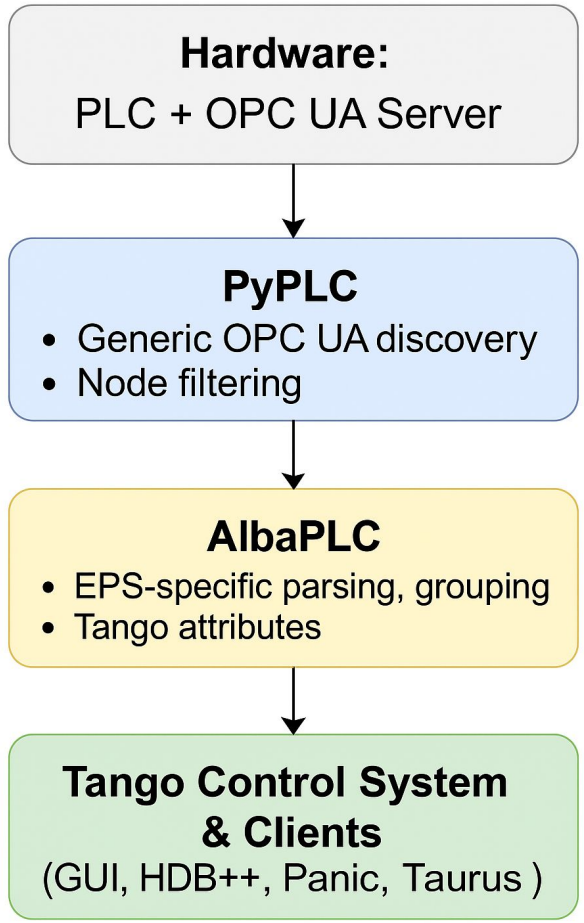
- Python Tango Device Server for **vendor-independent** PLC integration.
- We use client-server approach.
- Exploits *OPC UA*'s self-descriptive model. Dynamically discovers nodes at startup and creates attributes.
- Uses regular expression filters stored in *Tango DB* to select which nodes are read or subscribed.
- Uses *fandango.DynamicDS* to provide flexibility to customize attribute values with Python expressions.

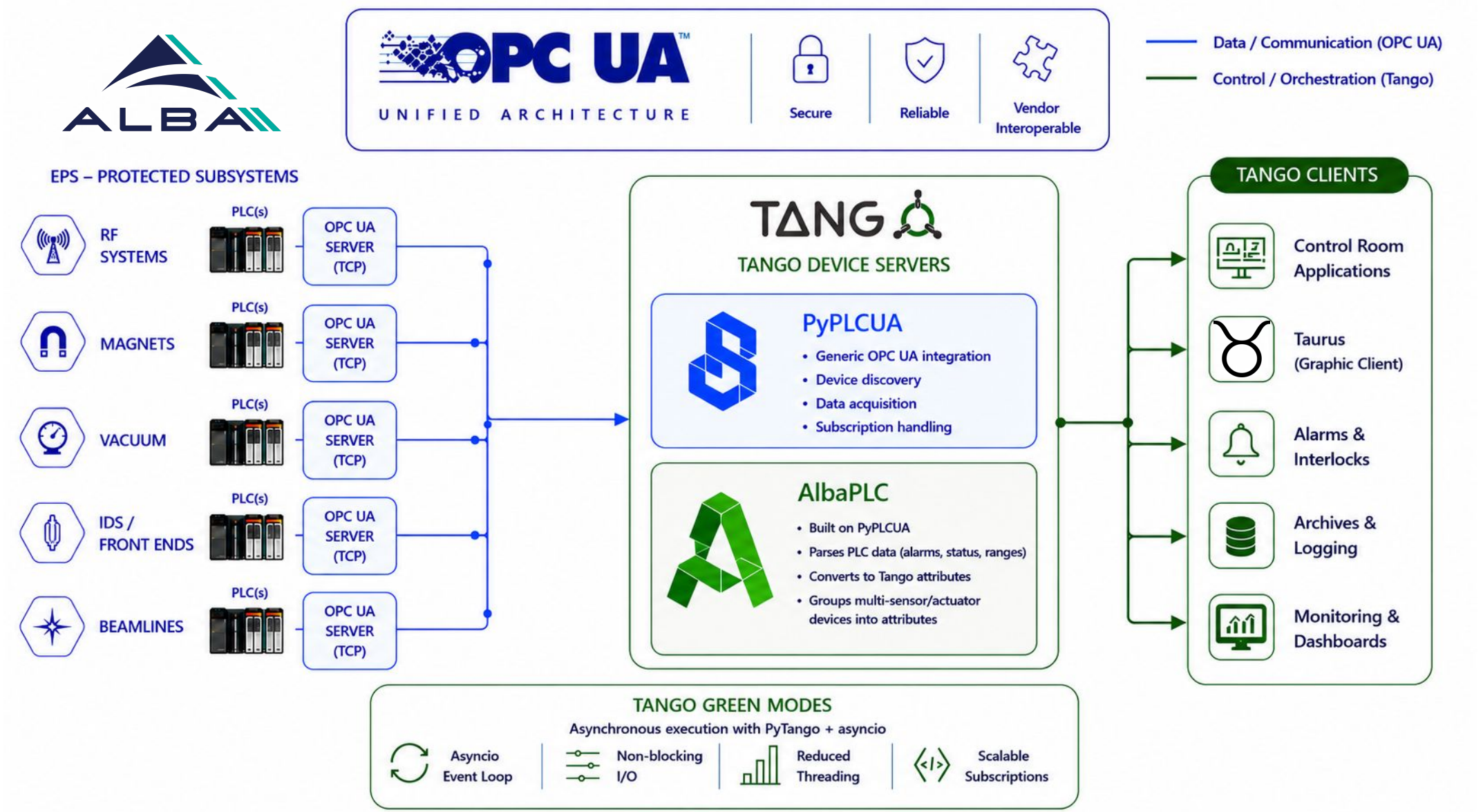




AlbaPLC - EPS-Specific Implementation

- Subclass of PyPLC tailored to ALBA's Equipment Protection System (EPS).
- Parses PLC EPS Library structures (timestamps, alarms, status bits, ranges).
- Transforms raw OPC UA data into Tango attributes with full quality and diagnostics.
- Groups multi-sensor/actuator devices (valves, shutters, masks) into Tango attributes.

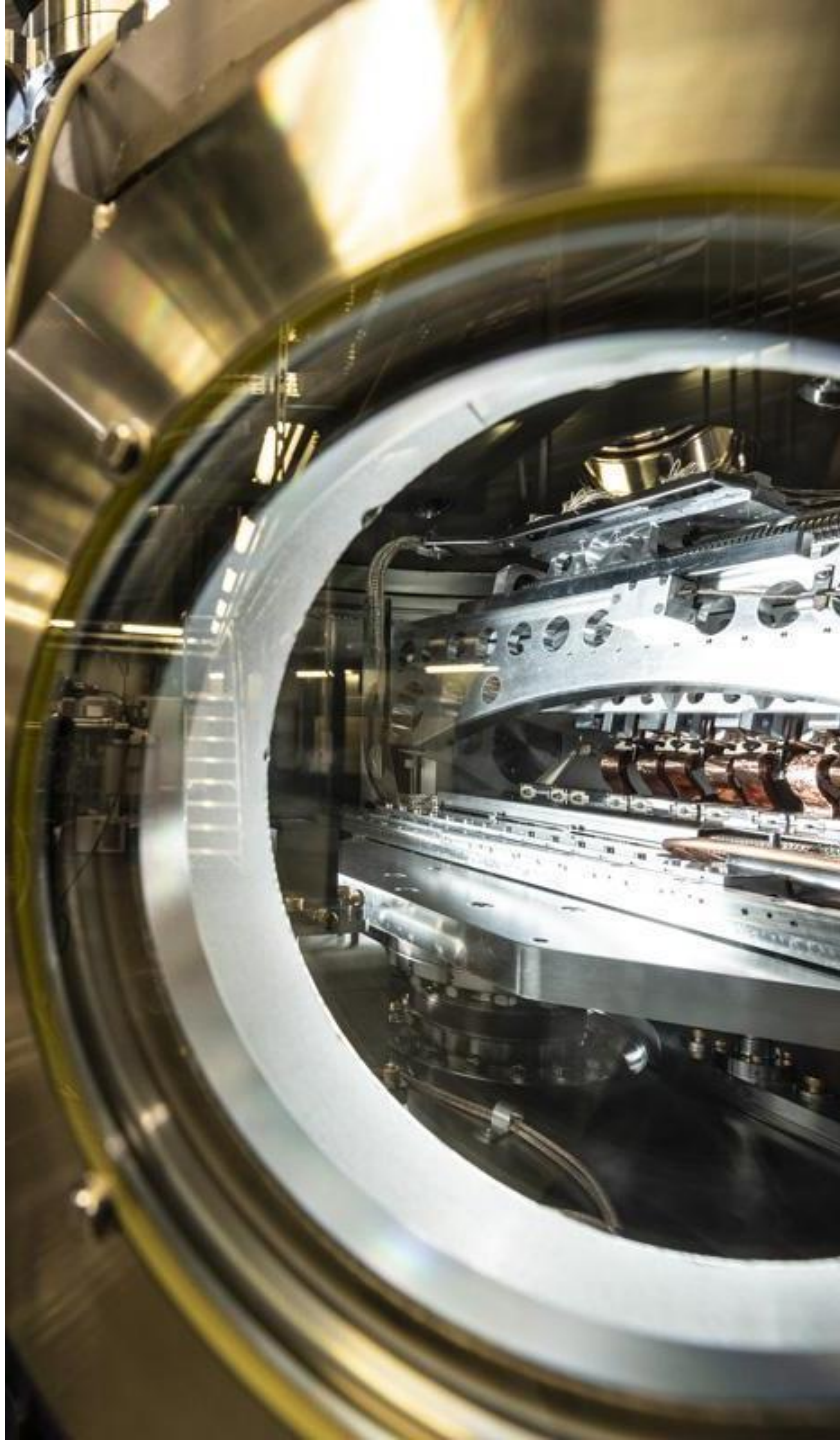



ALBA
OPC UA
UNIFIED ARCHITECTURE
Secure
Reliable
Vendor Interoperable
Data / Communication (OPC UA)
Control / Orchestration (Tango)
EPS – PROTECTED SUBSYSTEMS
RF SYSTEMS
MAGNETS
VACUUM
IDS / FRONT ENDS
BEAMLINES
PLC(s)
OPC UA SERVER (TCP)
TANGO
TANGO DEVICE SERVERS
PyPLCUA
Generic OPC UA integration
Device discovery
Data acquisition
Subscription handling
AlbaPLC
Built on PyPLCUA
Parses PLC data (alarms, status, ranges)
Converts to Tango attributes
Groups multi-sensor/actuator devices into attributes
TANGO CLIENTS
Control Room Applications
Taurus (Graphic Client)
Alarms & Interlocks
Archives & Logging
Monitoring & Dashboards
TANGO GREEN MODES
Asynchronous execution with PyTango + asyncio
Asyncio Event Loop
Non-blocking I/O
Reduced Threading
Scalable Subscriptions

Benchmark comparison

- Benchmark tests using **B&R X20CP1584 CPU**
- Subscription update period of 50 ms
- Modbus registers are read in bunches of 112 with 20 ms wait time

Operation	Nodes	OPC UA	Modbus
Read 1 node	1	**4.14 ms**	60 ms
Read all nodes	1194	11562 ms	24720 ms
Values batch reading	206	18 ms	342 ms
Setting batch reading	782	**325 ms**	626 ms
Values subscription	412	**74 ms**	–
Cache refresh period	412	112 ms	342 ms



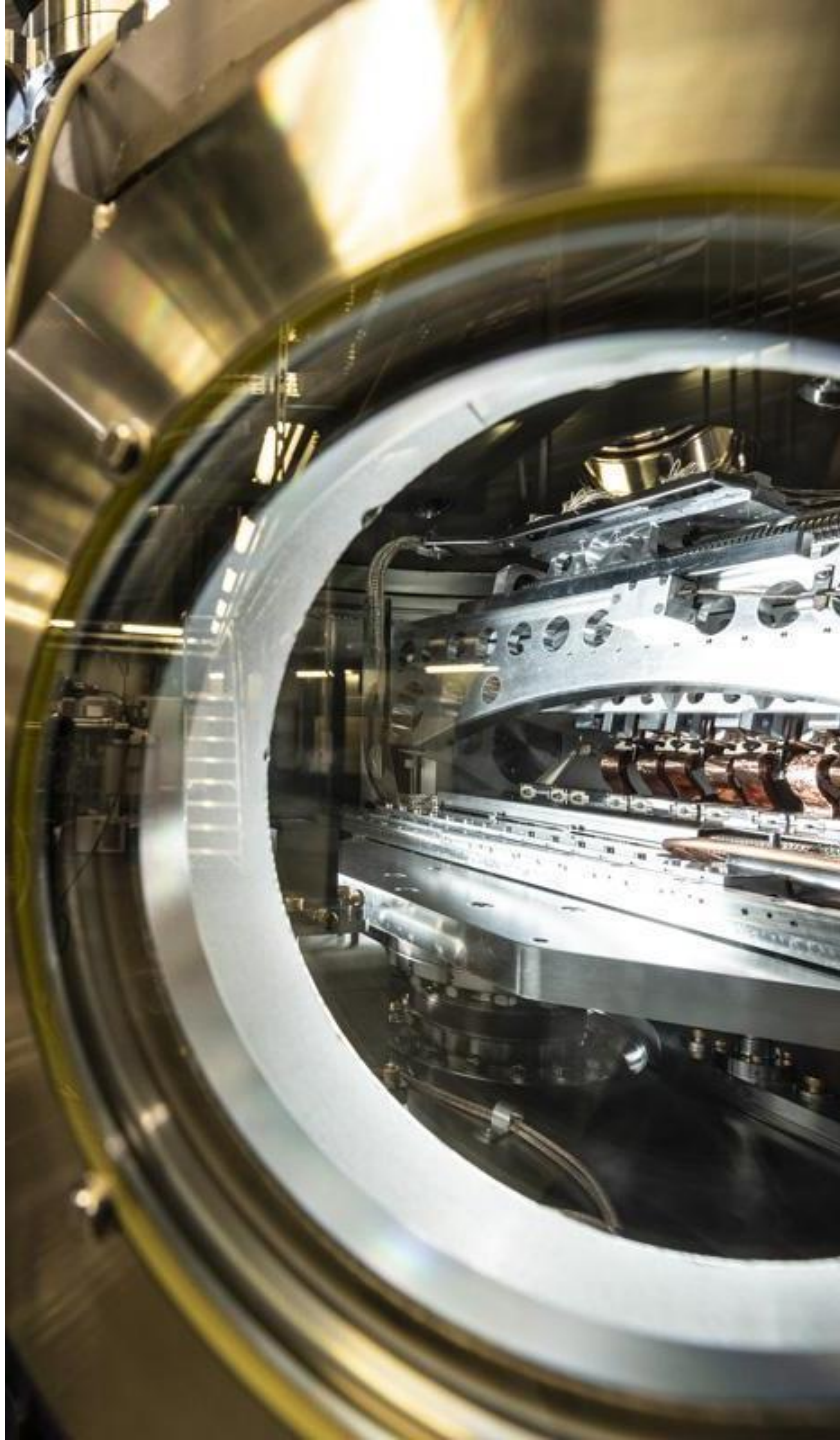
Benchmark comparison

Tests of full movement cycle of a valve:

Send Command → Initiate movement → Movement finished→ Client update

Protocol	min-max refresh time	average
OPC UA	90 - 270 ms	168 ms
Modbus TCP	170 - 1000 ms	499 ms

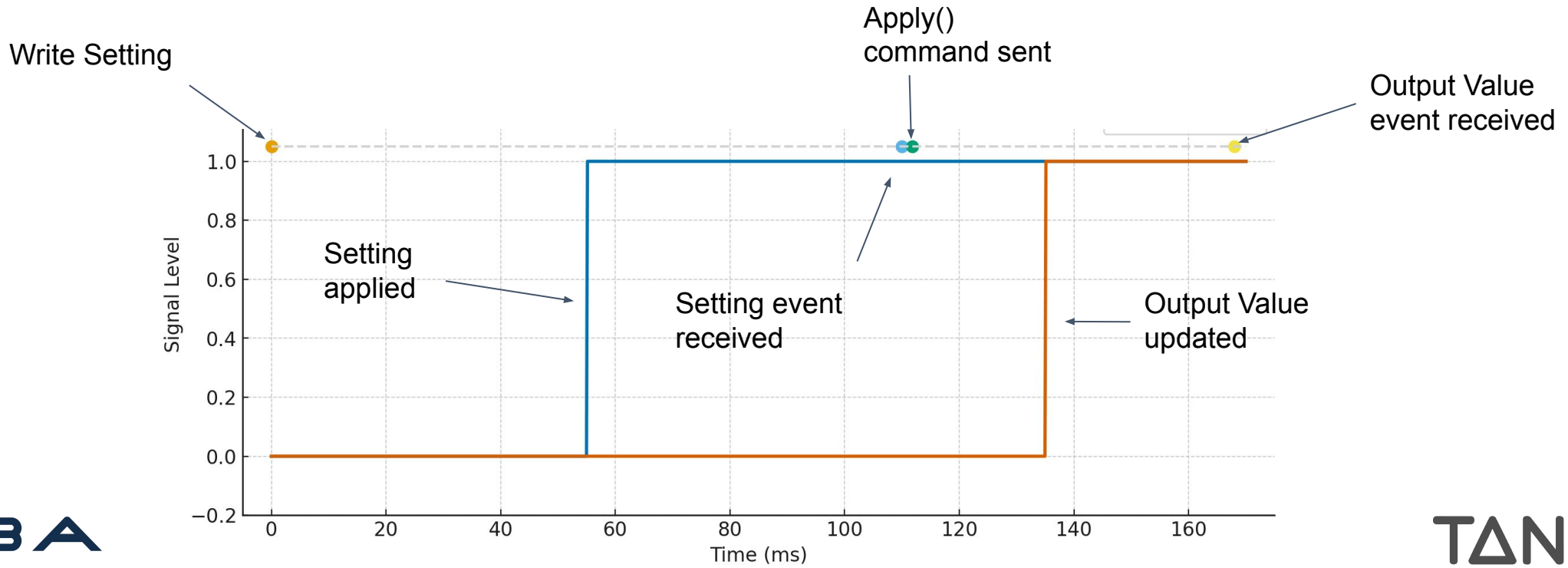
- OPC UA reacted at 168 ms on average, although with certain variability in response times .
- Modbus exhibited generally higher and more irregular response times, 499 ms on average.
- Modbus performance would be still significantly better for a number of registers below 100.



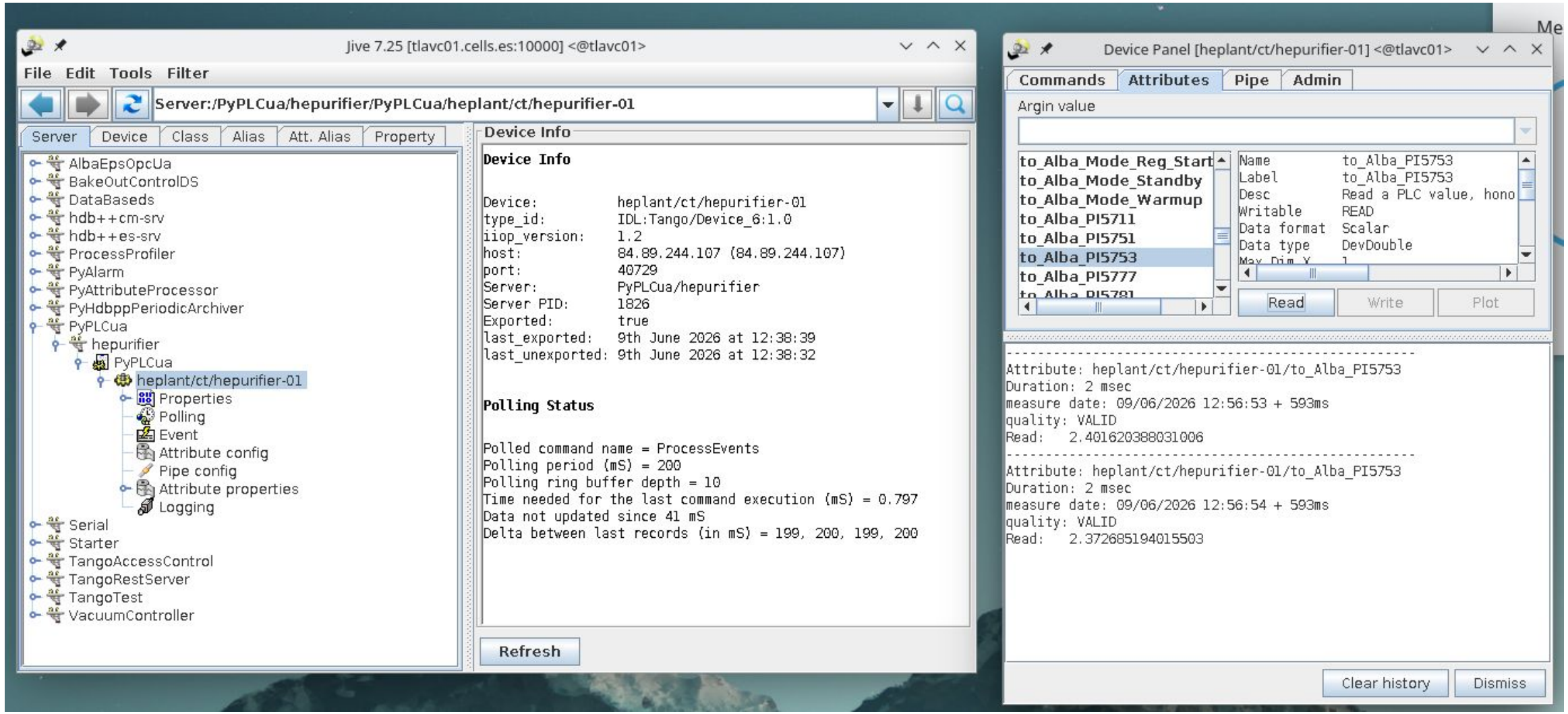
ALBA

Concurrency vs Serialization

- Asynchronous execution of commands does not guarantee the order at which they are completed.
- Under certain race conditions, when writing a setting value prior to an Apply() command, **command may be executed against the previous setting value!**
- AlbaPLC manages ongoing operations by using the MOVING state bit and the CHANGING quality, ensuring proper control and coordination of active processes.



Production PyPLCua Instance



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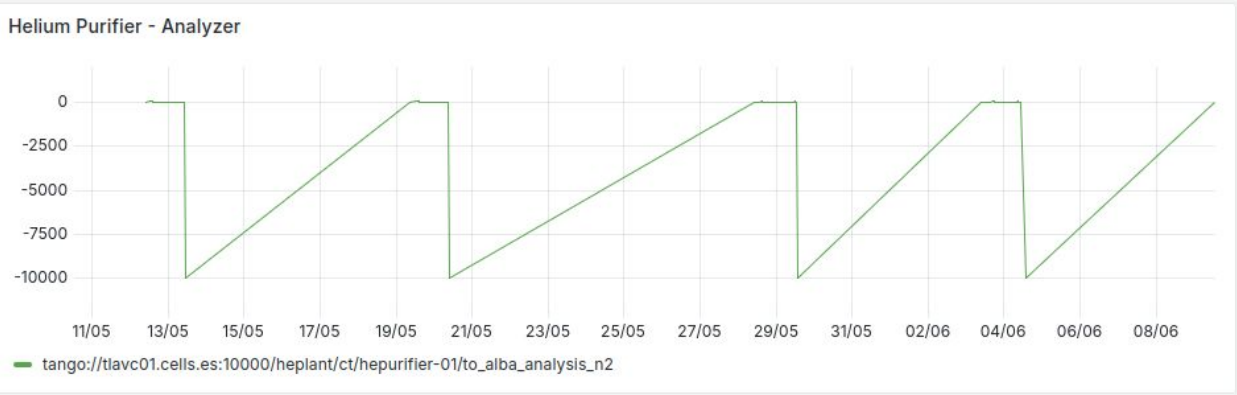
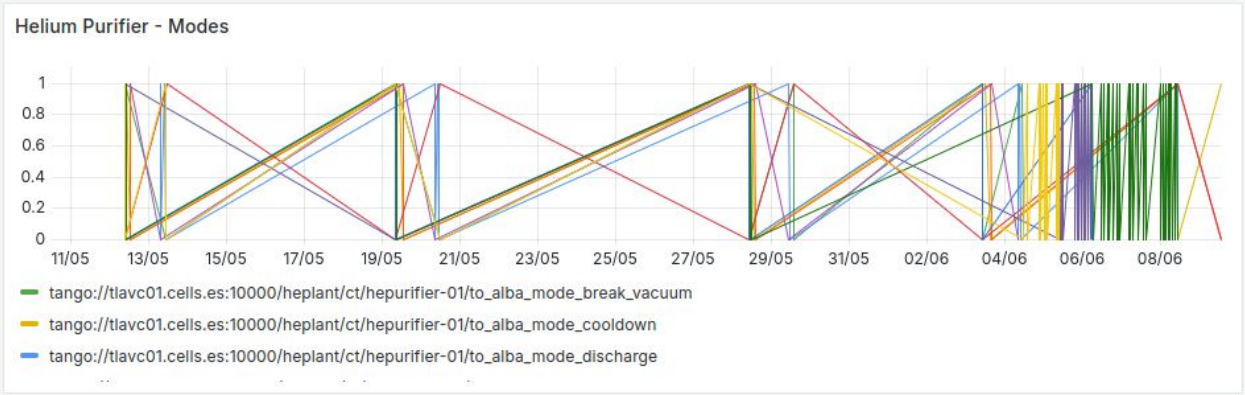
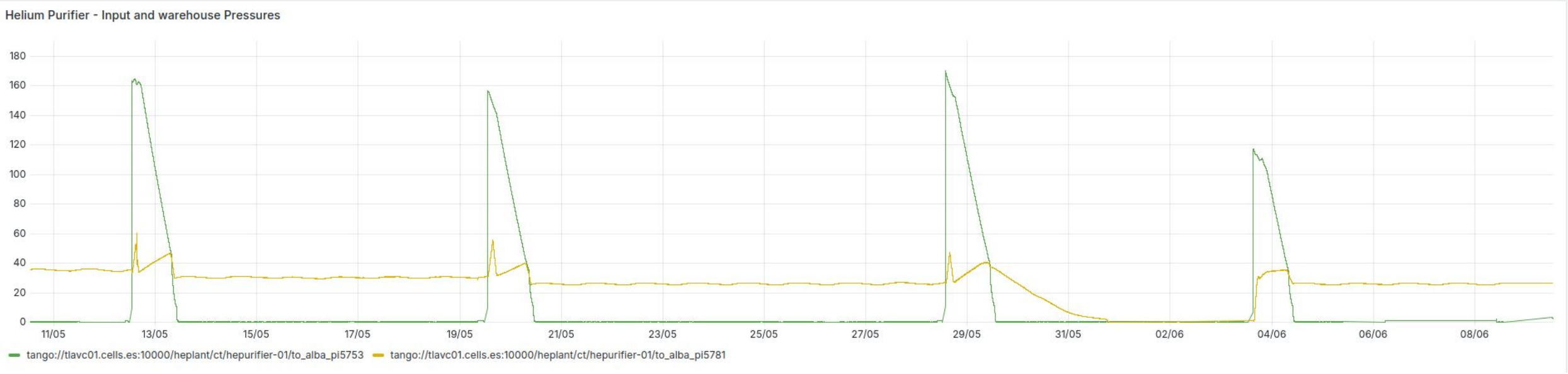




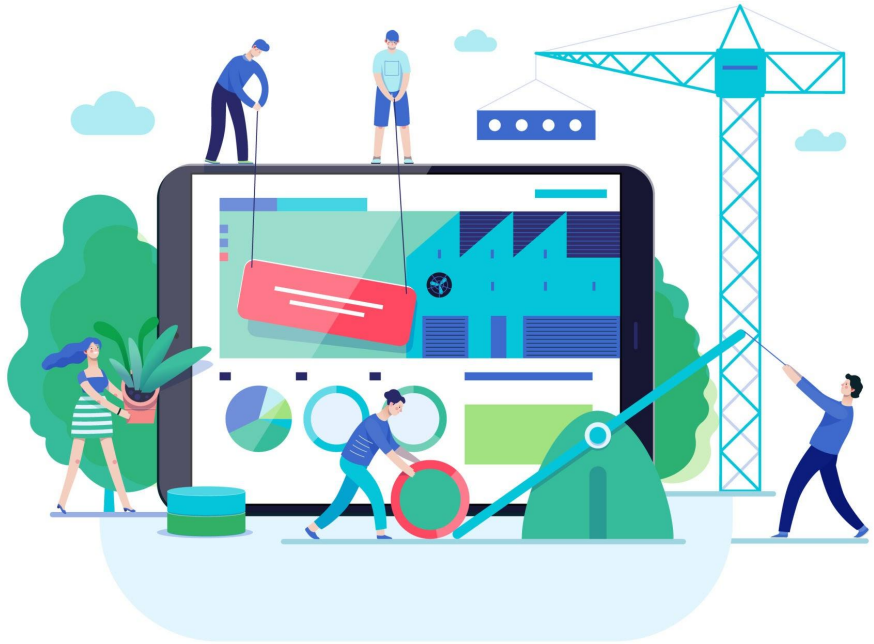


ALBA

TANGO

Testing Outside ALBA

- Tested by SOLARIS with Siemens PLCs.
  - We discuss about their experience.
- Tested at SOLEIL with Siemens PLCs.
  - They face some problems that are under investigation.
  - Next week we will meet with Patrick and Jade to clarify issues and requests.
- Thank you for your time and feedback!



Conclusions

- We have benchmarked our Modbus and OPC UA implementations
  - OPC UA shows **better performance**.
  - OPC UA **self-descriptive** nature eliminates the need for intermediate configuration files.
  - For small setups, Modbus is still a performant solution.
- We have developed a Python Tango device class to integrate OPC UA hardware.
  - Uses **asynchronous** programming.
  - It is **open-source** and available on GitLab. →
- We have tested with B&R PLC, let us know if you test it with another vendors!

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THANK YOU