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FULL STACK PLC TO EPICS INTEGRATION AT ESS

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Abstract

The European Spallation Source (ESS) is one of the largest science and technology infrastructure projects being built today. The Control Systems at ESS are essential for the synchronisation and day-to-day running of all the equipment responsible for the production of neutrons for the experimental programs. The standardised PLC platform for ESS to handle slower signal comes from Siemens, while for faster data interchange with deterministic timing and higher processing power, from Beckhoff/EtherCAT. All the Control Systems based on the above technologies are integrated using EPICS framework. We will present how the full stack integration from PLC to EPICS is done at ESS using our standard Configuration Management Ecosystem.

THE ESS PROJECT

The European Spallation Source (sketched in Fig. 1) is currently under construction in Lund, Sweden. The original ESS configuration was based on a 5 MW LINAC long pulse (2.86 ms) neutron source operating at 14 Hz, serving 22 neutron instruments. However, due to budget constraints, the accelerator power has later been reduced to 2 MW by decreasing the beam energy from 2 GeV to 800 MeV, and the total number of neutron instruments reduced to 15. The target station, on the other hand, is being built for the full 5 MW scope, since the reductions in the accelerator and instrument scope have been made in such a way that it can be restored at a later stage.

The reduction in accelerator power and instrument scope is largely offset by a significant improvement in the moderator design, resulting in a neutron brightness at the level of the original 5 MW design, and meaning the facility is still expected to be world leading shortly after it becomes operational. The first beam on target is expected in 2025, with user operation of the first few instruments planned for 2026 and the full 2 MW LINAC and 15 instruments operational at the end of 2027. For more details please see [1].

ICS AUTOMATION SECTION

The scope of the Automation Section, which is part of the Hardware and Integration Group (HWI), within the Integrated Control System division (ICS) at ESS, is to coordinate the design, develop, maintain and test of PLC Control Systems, keeping the life cycle documentation updated. It is also the scope of the Automation Section to coordinate the PLC-EPICS integration [2] via the software and web tools within the Control Management, to ultimately create Input/Output Controllers (IOCs) using the ESS customized EPICS environment called **e3** [3]. Further Automation Section responsibility is to develop and maintain, in close collaboration with stakeholders, operators, and graphic designers of the ICS software group, the relevant Operator Interfaces (OPIs), as well as the archive and alarm configuration. The generic layout architecture of a PLC-based control system is sketched in Fig. 2.

The Automation Section is composed by around 20 Automation Engineers, among ESS employees and consultants, grouped into different Work Packages. Each of them have its specific tasks and responsibilities to do PLC-based control systems integration of different parts of the ESS facility, in particular:

- LINAC
- Target
- Neutron Scattering Systems
- Conventional Facilities

PLC HARDWARE AND DEVELOPMENT & DEPLOYMENT SOFTWARE

The ICS division has adopted different standardised hardware technologies for implementing the ESS control systems based on performance, taking into account the required signal speed which should be covered while complying to the strict reliability and availability demands at ESS. The standardisation of these technologies makes the implementation cost-efficient and maintenance relatively simple.

For mid-range performance (< 100 kHz), industry standard Beckhoff/EtherCAT [4] systems are used to implement real time fieldbus applications (e.g. motion control systems) with a good price/performance ratio.

For conventional control systems to handle slower signal (< 10 Hz), the standard PLC equipment selected is Siemens [5]; this is a cost-effective solution which addresses ESS reliability and maintainability needs.

Siemens TIA Portal

The Totally Integrated Automation Portal (TIA Portal) is a software and tools package developed by Siemens, which aims to integrate multiple development tools for automation devices. It 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).

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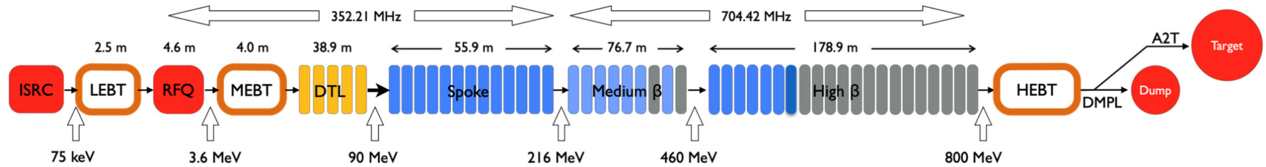

Figure 1: Current LINAC configuration for 800 GeV (grey cryomodules will not be powered). The commissioning up to the DTL tank 4 has been successfully carried up [6]. Next commissioning phases will cover the last DTL tank, the cryomodules and the Target station.

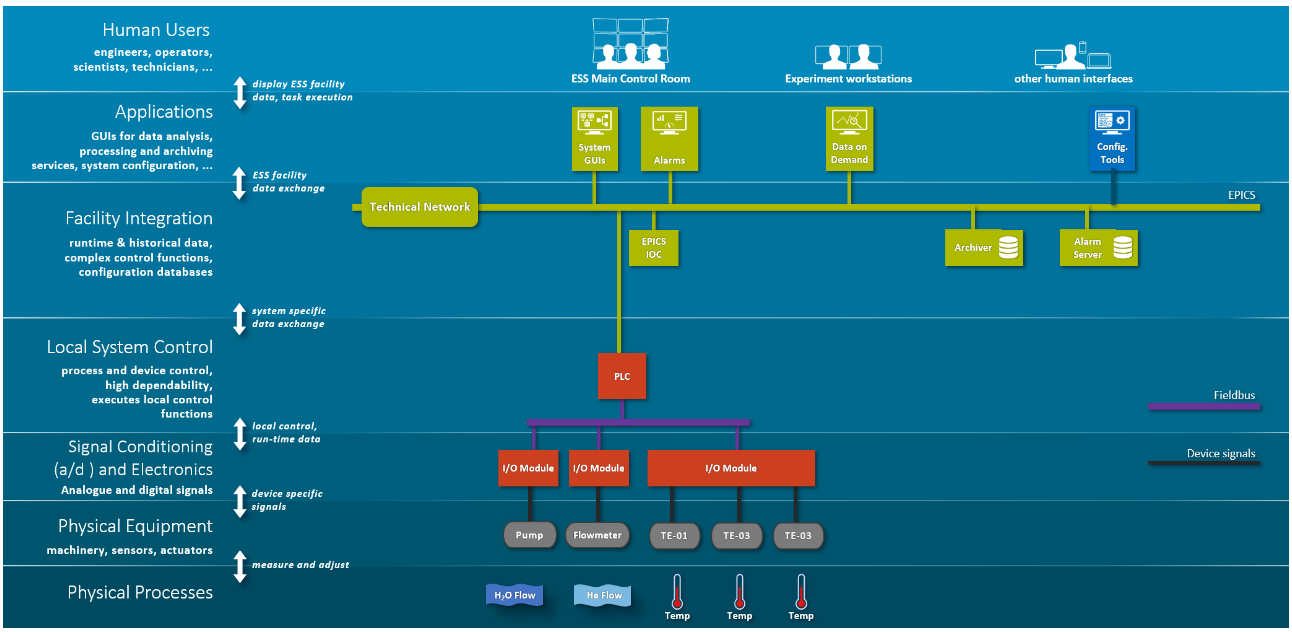

Figure 2: Layer Architecture of a PLC-based Control System.

Beckhoff TwinCAT 3

The Windows Control and Automation Technology (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. Its development environment is a shell of Visual Studio which is free of charge.

Versiondog

Versiondog is a version control and archiving tool to maintain PLC projects [7]. The PLC software version check is a part of the regular maintenance, but in addition it is performed during the periodic operational monitoring of systems. This means that every time there is a change in the PLC source code, archiving and versioning is done automatically.

PLC Safety control systems use a dedicated versiondog server because this way the access rights can be managed in an optimal way. The workflow is similar to non-safety PLC systems workflow.

Users can install versiondog client in their own laptop to access the server.

GitLab

GitLab is an open source software to collaborate on code where we manage git repositories, perform code reviews, and enhance collaboration with merge requests. The ESS GitLab server is used to store the EPICS IOCs source code/files, as well as the OPIs, and some configuration files.

GitLab is also used for archiving and versioning some Beckhoff/TwinCAT PLC projects, being a valid alternative to versiondog.

Development & Deployment VMs

A central maintained Windows OS (Windows 10 E LTSB) has been created with the purpose to perform PLC development & deployment. In more details, two clusters of Windows VMs with the same configuration and needed software (as previously described), were setup to deploy projects to PLCs which are connected to the ESS Technical Network for production, and 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 (see next section).

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Cyolo

In order to give users access in a safe and controlled way to the VMs connected to the TN, the Cyolo [8] remote access solution has been configured. Unlike traditional security models, this model requires that users authenticate before they can connect to a network resource based on identity-based access. 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, and more) or using the web user interface.

Another advantage is that if connected to the Cyolo App, users can access the Siemens License Server from their own laptop while connected to the office network, if they want to 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. It is a developers' tool, to primarily be used by control system/automation engineers within the ICS division. The ecosystem is composed of a number of different services and complimentary tools which are described in the following sections.

Naming Service

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*. The "Property" is basically the variable name known within the context of the device / system, which can be a measured quantity (temperature, flow, etc..), a status (on,off, etc...) or a command (start, stop, etc...).

A name format in combination with a set of syntax rules does not necessarily ensure a consistent and unique name. 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.

A REST interface is also available for the users, with several useful query options to get information about ESS Names, their elements and their history.

pvValidator

A complementary 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).

CCDB

To manage the very complex configuration of the ESS control systems, operators and engineers work with an abstracted model of the facility and the control systems. By modelling the control systems, operators and engineers can efficiently configure the local control systems in detail and then automatically replicate that configuration to be applied on other identical systems with a few simple commands. 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. A sketch of the CCDB modelling of a PLC-based Control System is shown in Fig. 3.

PLCFactory

PLCFactory 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. It is also capable of processing text files and substituting specially formatted expressions that are defined as properties in CCDB. The definition file, which basically is a configuration file which stores the Property of the device controlled by the PLC, is the source of information to the PLC Factory to be able to generate a set of code with linked variables for the PLC and the produced EPICS IOC source files. The communication protocol between PLC-EPICS is TCP/IP, i.e. step7 (PLC-to-IOC) and modbus (IOC-to-PLC).

Other features that PLCFactory can provide are the generation of alarm and archiver file configurations, and the generation of code to provide diagnostic information on the status of the communication between IOC and PLC.

CE Deploy & Monitor Tool

It is a deployment tool, that installs and manages the runtime of IOCs on a host machine. It is a Java application with a REST interface that allows creating, managing and monitoring IOCs in a standardized and centralized way across ESS. It uses Ansible playbooks to ensure a target host is in the desired state, including system configuration, IOC files and extra services.

The tool integrates with various other services, like the Naming Service, central log services, and allows for monitoring your IOC and performing a few select remote procedures.

The deployment tool ensures that IOCs are deployed in a controlled manner, eliminating the need to set up hosts and interface with common services available in the network. The tool also provides IOC configuration control and history, allowing for easy troubleshooting and the ability to revert to previous versions if necessary.

An overview of the PLC-EPICS integration workflow is shown in Fig. 4.

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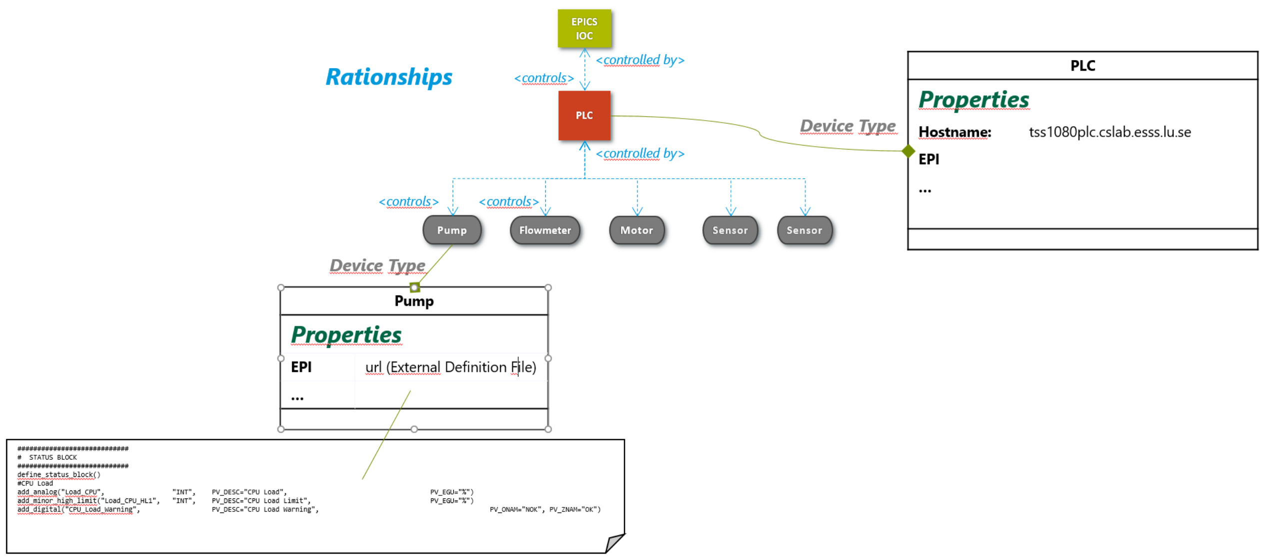

Figure 3: Modelling of a PLC-based Control System.

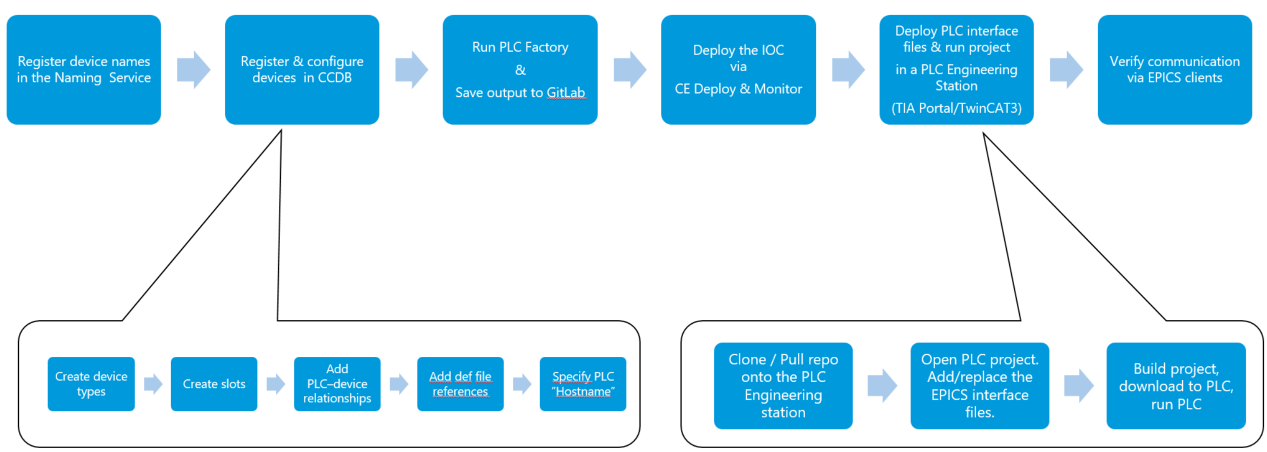

Figure 4: Overview of the PLC-EPICS integration workflow.

FUTURE UPGRADE

Control Management Ecosystem

As explained in the previous sections, currently the configuration of PLCs is stored in a database (CCDB) that describes the network of PLC devices and the controlling relationships between them, together with a domain-specific language used to translate these relationships into both PLC and EPICS code. The generation of this code is handled manually by an integrator running a custom python script (i.e. PLCFactory). However, the database in question 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. This is designed with a Java backend that provides a REST interface and a thin client that allows users to generate templated IOCs, as well as to deploy and monitor them. This will allow us to include the generation of PLC-based IOCs with the same toolchain and workflow that we use for all IOCs, together with having a much simplified data format to allow for the generation of all of the necessary code, together with allowing users some measure of automation via the given API.

Unit Test

Development of automatic unit test for PLC-based control systems, using e.g. pytest.

PLC-EPICS Communication Protocol

One of the limitations of the PLCFactory tool is that the only PLC-EPICS communication protocol available at the

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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 (Automation Device Specification) protocol is done manually. It is under evaluation the possibility to include the ADS protocol inside PLCFactory, and to align the local ESS ADS EPICS module to the one maintained by the ADS community.

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.

TwinCAT/BSD

Beckhoff offers also an alternative operating system, TwinCAT/BSD, for selected Beckhoff Industrial PC platforms. TwinCAT/BSD combines the TwinCAT runtime with FreeBSD, an industrially tested and reliable open source operating system. Being FreeBSD a UNIX like environment, it would be possible to run EPICS IOCs locally, avoiding the overhead of a VM [9].

CONCLUSION

We have presented how the full stack integration from PLC to EPICS is currently done at ESS within the ICS Automation Section, using our standard Configuration Management Ecosystem and the related complementary tools. We have described how we model PLC-based Control Systems and the entire workflow to produce the PLC code and the related EPICS IOC. We have also discussed the future upgrade of the Control Management Ecosystem and the possible implementation of new PLC-EPICS communication protocol (OPC UA).

We conclude saying that we are all engaged and highly motivated to give our contribution towards one of the main ESS milestone which is the first beam on target in 2025, as well as the others beyond.

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