An environmental monitoring and control system for the ATLAS ITk Outer Barrel QC and Integration*

Diego Alvarez Feito[a], Hans L. Joos[a,b], Susanne Kühn[a], Nicola Pacifico[a,*], Jarl N. Pettersen[a], Xavier Pons[a], Benedikt Vormwald[a]

[a] *CERN, European Organization of Nuclear Research, Esplanade des Particules, 1, Geneve, 1211, , CH*
[b] *University of Goettingen, Wilhelmsplatz 1, Goettingen, 37073, , DE*

Abstract

This paper describes the development of a system based on Programmable Logic Controllers (PLC) for safety interlocking and environmental monitoring during ATLAS ITk Outer Barrel (OB) loaded local support quality control (QC) and later integration. The system has been developed at CERN with a focus on scalability, maintainability and reliability, and is expected to be deployed at the different ITk OB loading and integration sites.

Keywords: ATLAS, ITk, Interlock, Integration, QC

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1. Introduction

The Inner Tracker (ITk) [1] will be one of the major upgrades that the ATLAS [2] experiment will undergo during the Long Shutdown 3 of the Large Hadron Collider at CERN. The ITk Pixel detector will be composed by an Inner System (IS), two Endcaps (EC) and an Outer Barrel (OB). The OB itself will be composed of 4,472 pixel modules, arranged on modular *local support* structures (*longerons* and *half rings*). In total, 158 local support structures will compose the OB. Quality Control (QC) testing will be performed at the different stages of production. Figure 1 offers a visual overview of the arrangement of local support structures in a half layer.

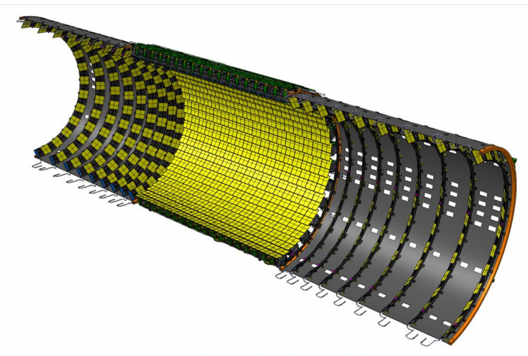

Figure 1: Half layer of the Outer Barrel (silicon shown in yellow). The middle part (*barrel half*) is composed by longerons supporting flat modules. The two ends, *inclined units*, are composed by *half rings* hosting modules tilted to enhance coverage at high η [3]. The OB will be composed of 3 full layers.

Dedicated environmental enclosures are being developed for the testing of local supports loaded with modules (*Loaded Local Supports* - LLS) providing the required connectivity to services (CO_2 cooling, power and data connectivity), light tightness and a safe operation enclosure during testing. A final QC test will take place at the integration stage, where sections of barrel halves and inclined units will be tested in the integration tooling equipped with a dedicated environmental enclosure. In order to ensure the safety of operation of several modules at the loaded local support QC testing and integration stage, a dedicated *Detector Control System* (DCS) and Interlock system was developed at CERN, based entirely on industrial *Programmable Logic Controllers* (PLC) solutions and providing a WinCC-OA interface. Such system is meant to be employed in a standalone configuration during LLS QC tests, while at the integration stage it will be coupled to the specific interlock crate developed as part of the ITk Pixel Detector Control System, the *Local Interlock & Safety System* (LISSY).

2. DCS and Interlock requirements

The system was designed to monitor both environmental and system-related parameters, taking mitigating actions (e.g. power supplies or cooling shutdown) in case of anomalies . Possible failure scenarios include:

- Failure of the cooling (CO_2) unit, resulting in a partial or total loss of cooling power;
- Low CO_2 vapor quality, sudden increase of temperature and pressure in an undefined point along the cooling line;
- Increase of relative humidity, and dew-point, above the cooling fluid temperature, with the potential of producing condensation on the device under test;

*Corresponding author
Email address: nicola.pacifico@cern.ch (Nicola Pacifico)

- Light leakage into the test enclosure, which would increase leakage currents in the front end readout chips and sensors;
- Defects at thermal interfaces, causing a temperature increase at the module level;
- Accidental opening of the test enclosure.

In order to intervene upon occurrence of these potential issues, an interlock system should monitor all the relevant parameters and take actions to mitigate the risk of damage to the structure under test. In the presented system, the Interlock matrix (containing the interlock logic) is implemented at the PLC level, ensuring a fast response. Depending on the failure mode, the matrix triggers independently the safe shutdown of low voltage and/or high voltage power supplies and a shutdown of the CO_2 cooling plant.

3. Hardware implementation

The system was designed to be able to operate in two different configurations, depending on whether it is paired to an LLS or integration setup.

During the QC testing of loaded local supports, the system is used autonomously. All signals are fed directly into the PLC modules, and processed by the PLC CPU, where the interlock matrix is integrated (see Figure 2).

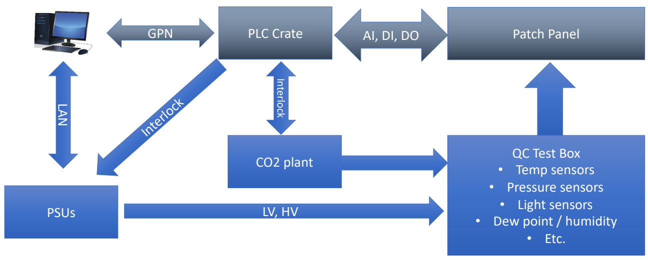

Figure 2: Stand-alone configuration for the Interlock/DCS system. The PLC crate reads analog and digital values from the environmental enclosure, and acts on the cooling plant and PSUs in case a criticality is detected. A monitoring PC communicates with it through the General Purpose Network (GPN) and handles the data storage and visualisation through a dedicated WinCC interface.

During integration, however, the number of module temperature sensors implemented in the interlock signal path (~ 56 out of 504 total) is too large and costly for a PLC-only system, requiring a large number of readout modules. For this reason, LISSY will be used to read out the module temperature sensors. This configuration, where the PLC system is in charge of monitoring environmental parameters while the LISSY is in charge of monitoring the modules temperatures is referred to as *hybrid* (see Figure 3). The PLCs used for this system are from the Siemens SIMATIC S7 line, with an S7-1500 CPU, providing adequately low latency times (< 1 s) for the readout of the modules. Excitation sources and connectivity to the system under test are provided by custom designed PCBs. PLCs and active electronics are integrated in a single 6U rack. Cables then depart to local fan-in boards, which can be installed in proximity of the environmental enclosure feedthroughs, allowing the direct connection of sensors through screw terminals.

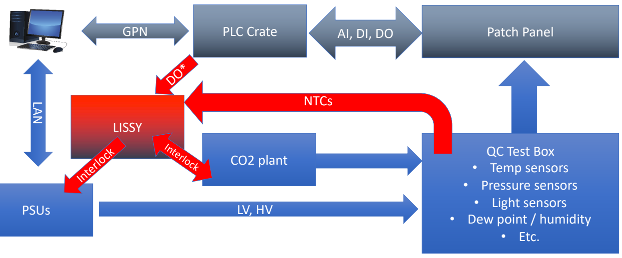

Figure 3: Hybrid configuration for the interlock DCS system. The LISSY crate reads the module temperature (NTC) information from the detector during integration, and triggers an interlock in case of temperature anomalies. Anomalies on the environmental parameters are still detected by the PLC crate, which sends an interlock condition to LISSY which triggers the appropriate actions.

4. User interface

An interface was developed in WinCC-OA, to provide monitoring and logging of environmental parameters and system status. The interface adapts dynamically to the system configuration (LLS/Integration) by means of a hardware bridge input set on the PLC crate. An example screenshot is provided in Figure 4.

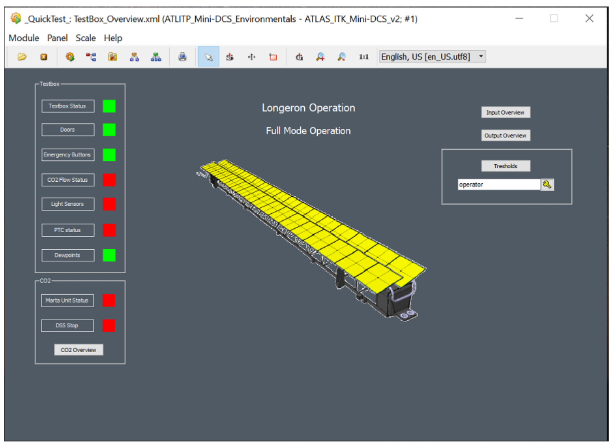

Figure 4: Screenshot example of a WinCC-OA status panel for environmental and status parameters monitoring.

5. Conclusions

The DCS and interlock system developed for the ATLAS ITk Outer Barrel LLS QC and integration was developed with a particular attention to system reliability. The choice of Industrial grade PLCs ensures a reliable operation and long-term support for the developed units. The first system is currently under test at CERN. It is foreseen to be produced in ~ 10 units and deployed at different sites as well as at the main integration site at CERN.

References

[1] ATLAS Collaboration, *Technical Design Report for the ATLAS Inner Tracker Pixel Detector*, CERN-LHCC-2017-021 ; ATLAS-TDR-030, `https://cds.cern.ch/record/2285585`

[2] ATLAS Collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*, 2008 JINST 3 S08003.

[3] ATLAS Collaboration, *Description of the Global Mechanics and Integration Sequence for the Outer Barrel*, AT2-IP-EN-0022 v.1, CERN EDMS 2438127