The Detector Control System of the New Small Wheel for the ATLAS experiment

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HEP2021

Recent Developments in High Energy Physics and Cosmology
18 June 2021
Thessaloniki, Greece
Contents

» Introduction to Large Hadron Collider & ATLAS
  » High Luminosity LHC
» New Small Wheel
  » System Overview
  » Hardware
  » DCS for Integration & Commissioning
» ATLAS Detector Control System
» NSW DCS
  » Architecture
  » Project/Server allocation
  » Projects
» Summary
The European Organisation for Nuclear Research:

- French-Swiss borders @ 60-100m underground!
- 27 km circumference
- Provide beams of p-p, p-Pb, or Pb-Pb ions
- Plenty of experiments

- Largest of four LHC experiments
- 7000 tonnes, ~100 million read-out channels, 3000 km of cables
- Contains 11 sub-detectors of different technologies in layer structure
- Built and operated by collaboration of >3000 physicists
- Operation with collisions since end 2009
High Luminosity LHC

- Run 3 will have a factor of ~1.5x increase in instantaneous luminosity
- The High Luminosity Large Hadron Collider (2027-...) will have 2-4x larger peak instantaneous luminosity compared to LHC Run 3 (2021 - 2024)

Present detectors:
- Cathode Strip Chambers (CSC)
- Monitored Drift tubes (MDT)
- Thin Gap Chambers (TGC)

- Tracking: Monitored Drift Tubes will lose efficiency at high hit rates due to higher instantaneous luminosity
- Triggering: Lowest unprescaled muon trigger is dominated by triggers not originating from the interaction point
The New Small Wheel (NSW) upgrade will replace the current Small Wheel of the ATLAS muon spectrometer to handle larger particle rates.

- Important for Run 3, vital for High Luminosity LHC (2028)

New Small Wheel detectors:
- Micromegas (MM), mainly for precision tracking, also for trigger
- Small Thin Gap Chambers (sTGC), mainly for trigger, also for precision tracking
NSW - System overview

- New detector technologies
- Custom ASICs and electronic boards
- New readout system based on FELIX
- 2.5 Million readout channels
- Common Configuration & DCS path
- New Power supply system
- Plenty of ATLAS & CERN infrastructure

The reality is more complicated

Next slide?
How to operate and control hundred of different devices and hardware?

Answer: Detector Control System (DCS)
- SCADA system equipped with UIs, scripts, etc
**NSW DCS: Integration & Commissioning**

- Prototype DCS projects have been developed in order to support the integration phase of the project.
- Majority of projects already deployed at integration & commissioning sites for further optimisations!
- The low-level segment of the projects has been fully deployed, with the main components (hardware’s daisy chain, OpcUa Servers, fw*, Datapoints schema, etc.) being fully functional.
- Commissioning of the whole NSW hardware via the DCS!
Due to its complexity and long-term operation, the NSW requires the development of a sophisticated DCS. The use of such a system is necessary to allow the detector to function consistently and safely as well as to function as a seamless interface to all sub-detectors and the technical infrastructure of the experiment.
ATLAS Detector Control System

- Facilitate management of implementation, operation and maintenance by using standard building blocks
- Controls hierarchy:
  - 1. Front-End (FE): detector interface
  - 2. Local Back-End (BE): FE connection, readout, processing
  - 3. Sub-detector BE: grouping different technologies, standalone operation
  - 4. Global BE: interfaces to operators, storage and external facilities

DCS Back-End

- Front-End interfaced to individual control stations (server PCs, Linux)
- Stations run SCADA software WinCC-OA (Siemens), allows distribution of applications
- Data exchanged via OPC (standard), Modbus (PLCs), DIM (anything else)
- Conditions data can be streamed to relational database (Oracle)
- Low level alarm system for individual parameters crossing thresholds

DCS Front-End

- Industrial Power Supplies & Crates (CAEN, Wiener, ISEG), read out and controlled via CAN/Ethernet
- Few PLCs read out via Modbus (managed by CERN infrastructure)
- Custom built low-cost I/O concentrator
- Sub-detector Front-End interfaces
The Detector Control System of the New Small Wheel for the ATLAS experiment

**State Machine Hierarchy**

- Detector control mapped to state machine hierarchy above SCADA layer
- Using JCOP FSM software framework
- Device States are propagated upwards using state rules. Commands propagated downwards
- Error handling upwards using parallel tree of Status objects linked to device alarm

**Operator Control**

- Alarm Screen enabling quick recognition and response to problems
- Homogeneous navigation through state machine hierarchy for operator with custom HMI
- Each state machine object has associated panel (synoptics, trends etc.)
- Access control mechanism
- Web monitoring, no load on Back-End, history mode
The Detector Control System of the New Small Wheel for the ATLAS experiment

**NSW DCS: Architecture**

NSW DCS architecture and its integration with the ATLAS DCS have been finalised

The plan is to have 2 new sub-detectors:

- **MMG (Micromegas)**
- **STG (sTGC)**

**Main projects:**

- High Voltage
- Low Voltage
- Electronics
- MDM-ELMB
- VME-ATCA
- Cooling
- Gas
- Infrastructure

The Detector Control System of the New Small Wheel for the ATLAS experiment
NSW DCS: Project/Server allocation

NSW DCS will be distributed over 18 projects under 10 server racks.

| Project | Server Allocation Details |
|---------|---------------------------|
| MMG     | ATLMMGSCS, PCATLMMG01    |
| Side A  | ATLMMGHA/C, PCATLMMG01/02|
| Side C  | ATLMMGLVA/C, PCATLMMG03/04|
| INF     | ATLMUONSWMDM, ATLMUONSWINF1, ATLMUONSWINF2, ATLMUONSWINF3, PCATLMU03 |
| STG     | ATLSTGSCS, PCATLSTG01    |
| Side A  | ATLSTGHA/C, PCATLSTG01/02|
| Side C  | ATLSTGLVA/C, PCATLSTG03  |
| INF     | ATLMUONSWMDM, ATLMUONSWINF1, ATLMUONSWINF2, ATLMUONSWINF3, PCATLMU03 |
The Detector Control System of the New Small Wheel for the ATLAS experiment
NSW DCS: Projects

Low Voltage
NSW DCS: Projects

Electronics

- DCS, Configuration & Calibration are on the same SCA OPC UA path
Temperature & bField sensors

More by S. Tzanos on the next talk
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Gas & Cooling

ATCA

NSW DCS: Projects
Summary

- The NSW is a fully redundant trigger and tracking detector system supported by an advanced electronics scheme and ready to handle the challenges of increased instantaneous luminosity at the HL LHC.
- Due to its complexity and long-term operation, the NSW requires the development of a sophisticated DCS.
- DCS is necessary for commissioning the equipment and the detector.
- Prototype DCS projects have been developed in order to support the integration phase of the project.
- Majority of projects already deployed at integration & commissioning sites for further optimisations!
- The low-level segment of the projects has been fully deployed with the main components being fully functional.
- NSW DCS architecture and its integration with the ATLAS DCS have been finalised.
- Currently, we are on the phase of NSW DCS optimisation towards P1 installation.
Thanks for your attention!

- Questions?
- Comments?
OPC Unified Architecture

Industrial machine-to-machine communication protocol for interoperability

- Originally developed by OPC Foundation for IoT applications (keyword Industry 4.0)
- OO Information modeling capabilities
- Enhanced security, performance and scalability
- Supports buffering, session mgmt, pub-sub, per-connection heartbeats/timeouts, discovery
- Multi-platform implementation, lightweight embedding possible
- Commercial SDKs available with stack from OPC foundation or open source stack implementations (C, C++, Java, JS, Python) for servers and clients

🎉 Excellent experience in ATLAS since 2012
- Fully supported by JCOP
- Still requires expertise and effort in programming with OPC UA ...
🎉 Provide development environment and generate OPC UA related code?
NSW DCS: Projects

NSW DCS: Projects

- ATLMUOŃSWMDM
- ATLMUOŃSW1
- ATLMUOŃSW2
- ATLMUOŃSW3

- ATLSTGSCS
- ATLSTGHVA
- ATLSTGHVC
- ATLSTGLVA
- ATLSTGLVC
- ATLSTGELTXA
- ATLSTGELTXC

- ATLMMGSCS
- ATLMMGHVA
- ATLMMGHVC
- ATLMMGLVA
- ATLMMGLVC
- ATLMMGELTXA
- ATLMMGELTXC

NSW DCS will be distributed over 18 projects under 10 server racks