

THE CONTROL SYSTEM OF THE ATLAS INNER DETECTOR

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Abstract

The Atlas detector at the LHC includes a composite tracking detector with a common infrastructure which includes the controls of the cooling circuits for Silicon detectors and of the active thermal insulation, the measurement of magnetic field, temperature, humidity, and radiation and the beam monitors. This paper describes the architecture of the Control System, the interplay among the various subsystems and the LHC controls and the operation experience both with cosmic rays and circulating beams.

INTRODUCTION

The Atlas experiment at the Large Hadron Collider at CERN will measure proton-proton collisions at a maximum centre of mass energy of 14 TeV. The whole Atlas detector has a shape approximatively cylindrical, with a diameter of 22 m and 46 m of length. It includes about 110 control systems. The Atlas detector is made of dedicated subdetectors: large area spectrometer for muons, calorimeters, for jet energy measurements and charged track spectrometer. The latter is the Inner Detector which can be subdivided into a barrel region and two endcaps. Each section is in turn made of a Transition Radiation Tracker (TRT), which uses straw tubes filled with an Ar-Xe admixture, a Semiconductor Tracker (SCT) using silicon strips, and a Silicon Pixel detector. The two silicon-based detectors share the same evaporative cooling system, while all 3 subdetectors have in common the environment, including gas, radiation and magnetic field. In this paper we describe the control system of the Inner Detector (ID) common infrastructure and some experience from several months of running.

THE ATLAS SCADA SYSTEM

The general organization of the Atlas slow control system is described elsewhere [1]. All the above mentioned systems, like all other experiments at the LHC, are supervised by a SCADA system, which is based on the software platform PVSSII [2]. The aim of every control system is to supervise all the operations carried out in its structure, to react promptly in case of dangerous events and to provide an operation interface (GUI). The detector control system (DCS) of the ID common infrastructure was designed according to a set of requirements: standard components were mainly used to reduce maintenance efforts, like PLCs (Programmable Logic Controller) and ELMBs (Embedded Local Monitor Board). PVSSII provides the link between the hardware components and the data structure of the DCS by using standard protocols, like Modbus and OPC. The DCS uses a Finite State Machine (FSM) model, which is

described in the next section. The DCS is also used to communicate among all the control systems in distributed environment, sharing all the important information for the detector. The structure is based on the DataPoint (DP), which is the data structure provided by PVSSII. Most of the data collected by the DCS are stored in the DataBase Oracle archive for future offline analysis.

FSM

The Finite State Machine (FSM) is a framework used to model the behavior of a system by means of limited number of states, transitions between states, actions and events. The ATLAS model uses the STATE and STATUS objects: the first one indicates the "operational mode of the system", the second "how well the system is working". The FSM of the Inner Detector infrastructure is hierarchically structured, reflecting the subsystems in which the system is divided. The most complex FSM tree in the common infrastructure is the one for the Evaporative Cooling system, as shown in Fig. (1).

DCS SUBSYSTEMS

Beam Condition Monitor (BCM) It detects anomalously high particle rate at low angle, close to the beampipe. This would cause background to the normal events of colliding protons, or high radiation dose. The BCM reads out 8 double-sided diamond detectors, so the PVSS system has to deal with just 16 LV and HV channels. In addition, the DCS system provides threshold voltages for the discriminators, low voltages for the readout board, for a total of about 400 control quantities. It also monitors the particle counting rate, which is uploaded every second from a FPGA board and displayed in panels. The controls for this subdetector have to be particularly reliable, because a LHC beam abort signal is produced when a too high particle rate is detected, so the BCM is part of the active protection of the Silicon-based detectors against beam accidents. The system has been functioning for one year, and the so-called "splash events" of 450 GeV beam on a collimator were recorded as an increase of rate in BCM.

Beam Loss Monitor (BLM) like the BCM, it is also based on diamond detectors, but it is read out with a longer time constant and is better integrated with the LHC beam loss monitor system.

Nuclear Magnetic Resonance (NMR) The NMR system monitors the magnetic field strength at 2 points at $z = 0$ outside the SCT. It provides a precise field value

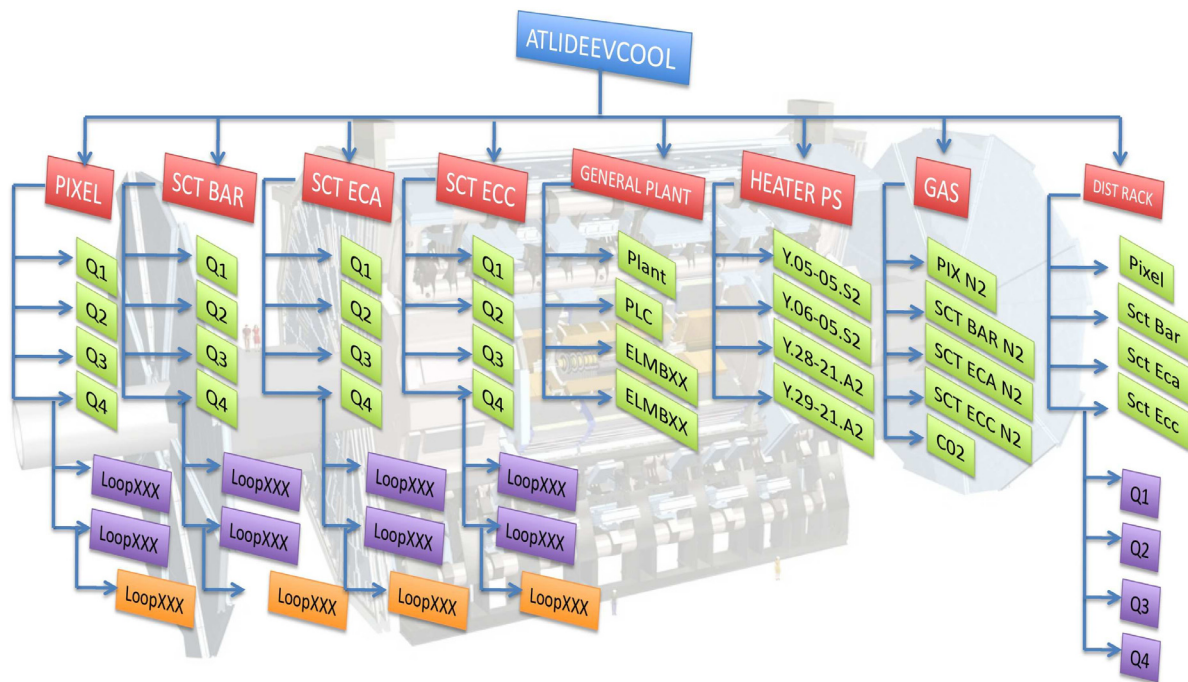


Figure 1: Evaporative Cooling DCS FSM tree.

which can be used to scale the field map. It is based on a Teslamer PT2025 which is read out via a RS232. The panel indicate the field values and the NMR latch condition.

Radiation Monitor (RADMON) The IDE will be operated in a high radiation environment. The RADMON measures the total ionising dose and the non-ionising energy loss at various locations in the detector. These measurements are vital for understanding the changes in performance during the operation of the experiment, verifying simulations and thus giving a chance to plan a better operation scenario. Moreover, it also provides on-line information about the degradation of the bipolar transistors performance. The control system performs I-V measurements on 14 sensor modules every 30 min. Each module carries 8 active devices and one NTC temperature sensor. The system also deals with the calibration constants and displays the results as doses or fluences. No action is required apart from recovery actions.

Environment This subsystem monitors about 1200 sensors in various parts of the ID: 40 integrated humidity and temperature sensors monitor the gas environment and dew point inside the ID volume, which is particularly important during servicing when the detector is open. Additional 150 sensors monitor the temperature in various parts of the inner volume, including zones with high density of cables, 56 temperature sensors monitor the cooling pipes, while 524 NTC's monitor the temperature of the coolant fluid. In addition, this

system also monitors the pressure and the temperature of the fluid at the distribution racks. The main FSM operations deal with recovering the ELMB from malfunctioning.

Thermal Enclosure Heater pads are used to thermally shield the TRT, which operates at 20° C from the SCT volume, which can be as cold as -25°C. The pads are instrumented with NTC which are used by an ELMB to regulate the current to the pads. The ELMBs are located on the power supply boards and run a PID-based regulating firmware. The control system monitors the temperature values and deals with the alerts which can be generated by the ELMB or by the control system, supervises the turning on and off of single pads and performs the recovery procedure and interlock resets.

Evaporative Cooling The semiconductor detectors require active cooling to remove the heat generated by the front-end electronics. The sensor crystals also need to be always kept at low temperature to maximize their lifetime as a detector in a high radiation environment. A sophisticated evaporative cooling system is in place. It allows a silicon operating temperature of -25° C and is able to remove a total 60 KW of heat. The same cooling plant serves both sub-detectors. It includes 7 compressors which can work in parallel, one condenser and one liquid pump at the outlet of the condenser. The detector structures are cooled by 204 independent cooling circuits, which are tuned according to the sub-detector operational requests. The temperature stability within the ID vol-

ume must be maintained within 2° C. All regulation actions are taken by 3 PLC's, one of which interacts with the PVSS system via Ethernet Modbus. The control system sends to the PLC the set of parameters for each group of circuits, and the required state for individual circuits. The corresponding FSM is divided in 4 trees for pixels, SCT barrel and each SCT end cap. A handshake mechanism between systems can be activated to turn on automatically the low voltage silicon power supplies when the corresponding cooling circuit is activated via FSM, while some system protection scripts automatically turn off all the voltages when the cooling circuit is not in ON state. This control system has been continuously in use for about one year, proving to be very reliable.

ATLAS DCS WEB VIEWER

The DCS data from the various ATLAS sub-detectors are stored in an Oracle database using the standard schema provided by PVSSII. A fast off-line analysis of these data is vital for troubleshooting and to understand any event which may happen during commissioning and operations.

We produced a web-based tool to search the ATLAS DCS Oracle database and to display the results. This tool has been easily extended to access the data from all the other ATLAS sub-detectors, allowing cross-system searches. The web interface is shown in Fig. 2 and is based on PHP. We require that all the queries are performed over a well defined time interval, excluding open-ended queries.

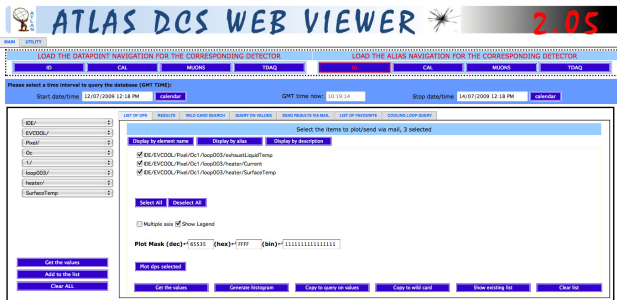


Figure 2: The user interface of the Atlas Dcs Web Viewer.

The peculiarity of this project is that all database accesses take place at the server side, while the client side deals with data point navigation, DP list editing and data display. The datapoint navigation uses an XML file, which is refreshed twice a day at the server side, to access single data points. Search on element names, alias or descriptions is also available using a wild card search. The list of all data points which had values within (or outside) a user specified range, or matching a given bit pattern, can be retrieved with a query on values and was proved very useful to find anomalies. In addition to display the recorded values as a function of time, as shown in Fig. 3,

Status Report

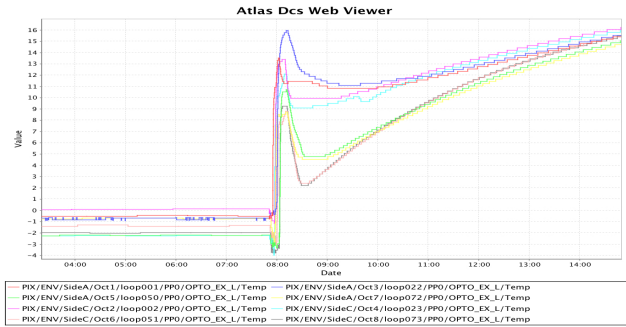


Figure 3: Example of a trending plot from the Web Viewer.

This tool can also provide in a web page the histograms of maximum, minimum and average values of the elements in a user defined list, as shown in Fig. 4. The list can be originated by a name pattern, by a query on values or by selecting individual elements. The display is based on free-ware [3] and allows interactive zoom in. The data can be saved in text or csv format.

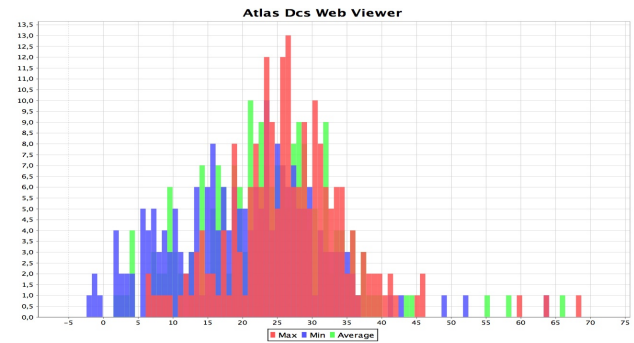


Figure 4: Example of a histogram from the Web Viewer.

REFERENCES

- [1] A. Barriuso Poy *et al.*, "The detector control system of the ATLAS experiment," JINST 3 (2008) P05006.
- [2] PVSS is produced by ETM GmbH, Kasernenstraße 29, A-7000, Eisenstadt, Austria, <http://www.etm.at/>
- [3] *jfreeChart*, <http://www.jfree.org/jfreechart/>