STATUS OF THE ATLAS DETECTOR AND COMMON INFRASTRUCTURE CONTROL SYSTEM

O. Gutzwiller, H.J. Burckhart, S. Franz, S. Schlenker, CERN, Geneva, Switzerland
V. Filiminov, V. Khomutnikov, PNPI, St-Petersburg, Russia
L. Sargsyan, YerPhI, Armenia

Abstract

The ATLAS experiment is one of the experiments at the Large Hadron Collider (LHC), constructed to study elementary particle interactions in collisions of high-energy proton beams. The Detector Control System (DCS) has the task to permit coherent and safe operation of ATLAS and to serve as a homogenous interface to all sub-detectors. The DCS also provides control for the Common Infrastructure Control (CIC) system and manages the communication with heterogeneous external control systems. During the start-up phase of the LHC, the DCS has continuously been used and is a key element to operate the detector.

INTRODUCTION

ATLAS is a general purpose High Energy Physics (HEP) experiment, scheduled to start data taking for end 2009 at the LHC accelerator at CERN, Geneva, Switzerland. Its scale is unprecedented in HEP, in both terms of size – the detector elements are distributed over a cylindrical volume of 25m diameter and 50m length – and organization – more than 2000 people of 167 institutions in 37 countries contribute to the project [1]. To ensure safe operation of the detector and the electronics, a highly distributed control system, the Detector Control System (DCS), has been implemented [2].

The DCS enables equipment supervision using operator commands, reads, processes and archives the operational parameters of the detector, allows for error recognition and handling, and provides a synchronization mechanism with the physics data acquisition system. Finally, the DCS has to handle the communication between the ATLAS sub-detectors and other systems which are controlled independently. The DCS Back-End (BE) is organized as a hierarchy of finite state machines, allowing for the homogenous control of the whole detector by a single operator. Distributed I/O concentrators, called Embedded Local Monitor Boards (ELMB), have been developed to operate under the special conditions of the experiment and facilitate the integration of Front-End (FE) devices.

This paper focuses on the architecture and implementation of the ATLAS DCS and its operational aspects. Additionally a detailed description of the control of the common infrastructure is given.

OVERALL DESIGN

The ATLAS experiment is operated by two collaborating systems: the DCS and the Trigger and Data-Acquisition (TDAQ) [3] system. The former constantly supervises the hardware of the experiment and its infrastructure. The latter performs the read-out of detector data and operates only during physics data taking periods. The DCS is responsible for continuous monitoring and control of the detector equipment and is supervised by a human operator in the control room.

Since the ATLAS detector is located in a cavern 100m underground and is not accessible during operation because of the presence of ionizing radiation and magnetic field, the control system must be fault-tolerant and allow remote diagnostics. The ELMB [4], a purpose-built flexible I/O concentrator system developed for LHC experiments, fulfils ATLAS requirements and provides a standardized interface for a large variety of Front-End (FE) devices. It communicates with higher levels of the DCS using the CANopen protocol.

The main framework of the BE is a Supervisory Controls And Data Acquisition (SCADA) system called ProzessVisualisierungs- and SteuerungsSystem (PVSS II) [5] from the company ETM. The BE is a distributed system organized in three layers (see Figure 1): the Local Control Stations (LCS) for process control of subsystems, the Sub-detector Control Stations (SCS) for high-level control of a sub-detector allowing stand-alone operation, and the Global Control Stations (GCS) with server applications and human interfaces in the ATLAS control room for the overall operation. In total, the DCS consists of more than 150 PCs, for which PVSS handles inter-process communication via the local area network. The full BE hierarchy from the operator interface down to the level of individual devices is represented by a distributed Finite State Machine (FSM) mechanism allowing for standardized operation and error handling in each functional layer. Each logical unit in the ATLAS FSM is given a "State" of operation and a "Status" reflecting any anomaly in the FSM mechanism.

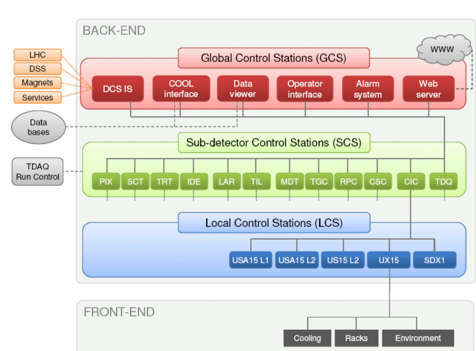

Figure 1: ATLAS DCS architecture.

The implementation of the DCS has been facilitated with the use of components provided by the JCOP Framework (FW) [6]. It consists of a set of guidelines, components and tools for the LHC experiments using PVSS and defines conventions to ease the implementation of homogeneous controls applications. The FW components also provide tools to integrate standard hardware devices such as the ELMB or commercial power supplies and provide all required functionality to monitor and control the detector electronics racks and cooling systems.

OPERATION LAYER

The DCS operation layer provides the top level interface between the DCS BE systems and human operators. Further, it provides tools for efficient problem diagnostics and handling by detector experts.

The DCS is operated from a dedicated station within the ATLAS control room. The station hosts the two primary user interfaces – the Alarm Screen for alarm recognition and acknowledgement and the FSM Screen for operation of the detector Finite State Machine hierarchy. The FSM is protected by an access control mechanism using predefined privileges for sending commands. To avoid the accumulation of a large number of alerts on the alarm screen, a filtering tool has been implemented in function of the originating control station, severity or identifier of the alarms. Moreover it allows the masking of individual alert until its value gets back in the valid range.

Further interfaces used on demand are tools for data visualization, process log viewer, and operator log book. Full remote access to all user interfaces is possible by a terminal server for expert operators only. Static status monitoring is provided by web pages on a dedicated web server world-wide [8]. An example of an operator interface of the ATLAS FSM is shown in Figure 2, representing the global state of ATLAS and each sub-detector.

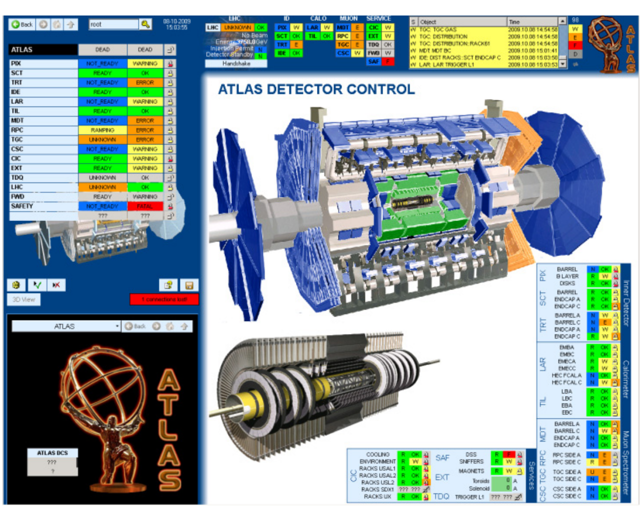

Figure 2: ATLAS FSM operator interface.

Due to the size of the control system, the large diversity of software elements and the long lifetime of the experiments, a centralized software management strategy was adopted for the ATLAS DCS. The use of PVSS has provided a common skeleton for the development and implementation of the individual applications thus facilitating long-term maintainability. The tools of the JCOP Framework have facilitated integration of hardware components in the DCS and provided software tools on a higher level. PVSS application elements such as user interfaces and Control scripts and libraries, as well as FW components are stored in a central repository located on a shared network drive and controlled by a software versioning system.

The DCS has also faced hardware failures like power supplies or ELMB. The strategy adopted by DCS was to acquire enough spare equipment, which might not be commercialized in the long-term future, to be able to recover from hardware failures.

Expert knowledge becomes an integrated part of the DCS itself and evolves as operational experience is gained with time. Special emphasis is put on the documentation of the system. This is particularly important as the experiment is scheduled to run for more than a decade and personnel will change.

COMMON INFRASTRUCTURE CONTROL

All parts of ATLAS which are not directly under the responsibility of a particular sub-detector are supervised by the Common Infrastructure Control (CIC). The CIC is part of the ATLAS FSM and provides monitoring of the global environment and control of the racks. The CIC also handles the communication with externals systems. The supervision has been handed over to a non-expert shifter which operates continuously all technical infrastructure.

Environment Supervision

The control of the environment conditions at ATLAS is based on the CIC infrastructure, a network of 700 ELMB located in the experimental area and in the counting rooms. During the last year the ELMB has been successfully used to integrate monitoring of additional parameters, which were not foreseen in the initial design, like the monitoring of the electrical installation or the control of the lights by driving relays.

The FE infrastructure of the CIC itself is also supervised, which allows to detect any ELMB failure in the FSM. During the 3 last years the CIC experienced about 4% of failures due to vibration of turbines, handling of the board during development or installation, effects after magnet field applied in the cavern. DCS has no experience with radiation yet.

Control of the Racks

The Rack Control application monitors 500 racks, enables equipment supervision, sending commands and archiving the operational parameters for each rack.

The status information of the electricity distribution is read from PLCs into PVSS. A framework handles the communication though an Ethernet connection, from a master PLC (Premium) which controls local PLCs (Twido). Commands can be sent to act on the powering of the racks.

The racks in the experimental area are equipped with a Turbine Unit to ventilate and cool the air. An ELMB placed in the Turbine Unit monitors parameters, like temperatures, humidity rates, dew point, turbine currents, etc... Additional sensors for specific needs (i.e. leak detection) have easily been interfaced. The TDAQ racks are cooled with fans and heat exchangers placed on the rear doors.

A software layer using the FSM has been developed to provide control of the racks from the control room. The operator interface allows visualizing the state of a counting room up to an individual rack represented by a state machine. The panel for a rack displays the parameters measured and the equipment it houses.

Connection to External Systems

The data exchange between the ATLAS DCS and external control systems is handled via the Data Interchange Protocol (DIP). This protocol is a thin layer on top of the Distributed Information Management (DIM) process communication interface [9] designed for highly reliable event-based data transfer. A DIP server publishes data items to a dedicated name server. A client process can fetch the server publication information from the name server and can subscribe at the DIP server to selected data items, resulting in an event-triggered data transfer from the server to the client.

The external control systems are connected to the DCS using a dedicated Information Server in the GCS layer. Information from the external systems is transferred via DIP to the DCS. A generic error handling mechanism using the DIP quality monitoring facilities has been implemented for all subscriptions on the DCS IS signaling any error condition related to the DIP communication.

Each of the gas systems, magnets and cryogenics of the different sub-detectors is controlled by a dedicated PLC. The PLC is supervised by a stand-alone PVSS system, which is not part of the ATLAS distributed control system.

The interaction between ATLAS and the LHC control is handled by dedicated instrumentation on both sides providing detailed information about luminosity and backgrounds via the DIP protocol. The state of the LHC accelerator is presented to the operator by the DCS and a semi-automatic handshake mechanism has been implemented to signal the readiness of the detector for beam related actions of the LHC such as beam injection, adjustment or dump.

A Beam Interlock System (BIS) combines signals in ATLAS indicating high backgrounds, and in case of danger for the detector sends a hardware interlock signal to the LHC in order to dump the beams. The status of the BIS is presented by the CIC as an FSM unit.

CONCLUSIONS

In order to achieve a homogenous control system for the whole of ATLAS, the DCS BE applications, distributed within a network of dedicated control stations, are hierarchically structured following the natural segmentation of the detectors with several functional layers. Strong emphasis was put on guidelines and development conventions and on the implementation of common application components. The monitoring and control of each part of the control hierarchy is provided by a finite state machine mechanism, which effectively reduces the complex set of FE component states of the different ATLAS sub-detectors to a single overall state. Efficient error recognition and handling is provided by a centralized alarm system.

The use of common tools and strategies on the BE level has the advantage to facilitate long-term software maintainability. On the FE, the ELMB has been developed to fulfil ATLAS requirements and ease sensors or actuator interfacing. In addition to the sub-detector control applications, supervision of the common infrastructure was implemented and is now routinely running. Furthermore, external systems are interfaced coherently using a multi-platform communication protocol and are integrated within the common control mechanisms.

During the start-up phase of ATLAS, it was proven that the DCS scales up to the level needed and is able to continuously provide stable detector operation.

REFERENCES

[1] The ATLAS collaboration, J. Inst, *vol.3, p. S08003, 2008.*

[2] Barriuso, P., et al., J. Inst, *vol.3, p. P05006, 2008.*

[3] ATLAS TDAQ Collaboration, "Integration of the trigger and data acquisition systems in ATLAS," proceedings of the International Conference in High Energy Physics (CHEP'07), Victoria BC, Canada.

[4] Hallgren, B., et al., "The embedded local monitor board (ELMB) in the LHC front- end I/O control system," *proceedings of the 7th Workshop on Electronics for LHC Experiments, Stockholm, Sweden, 2001.*

[5] ETM professional control GmbH, "PVSS II SCADA Product", http://www.pvss.com/.

[6] Holme, O, et al., "The JCOP framework," proceedings of the 10th International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS 2005), Geneva, Switzerland, 2005.

[7] Franek, B., et al., IEEE Trans. Nucl. Sci., vol. 52, pp. 513–520, 2004.

[8] ATLAS DCS Operation, http://pcatdwww.cern.ch/atlas-point1/dcs/.

[9] Gaspar, C., et al., *Comput. Phys. Commun., vol 140, pp. 102-109, 2001.*