THE TILECAL DCS DETECTOR CONTROL SYSTEM*

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Abstract

TILECAL is the barrel hadronic calorimeter of the ATLAS detector that is being built at CERN. The main task of the TILECAL Detector Control System (DCS) is to enable the coherent and safe operation of the detector. All actions initiated by the operator and all errors, warnings, and alarms concerning the hardware of the detector are handled by DCS. TILECAL DCS design is being finalized. The main systems are now being implemented and some are already in use for the TILECAL tests and certification.

INTRODUCTION

TILECAL the barrel hadron calorimeter of the ATLAS detector, is a sampling calorimeter made of scintillating tiles readout by wavelength shifting fibres, using iron as absorber and photomultipliers (PMT's) as photodetectors [1]. The PMT's and part of the front end electronics [2] are located on the outer side of the modules. TILECAL is composed of 3 cylinders, one central barrel and two extended barrels. Each cylinder composed of 64 modules.

The DCS is responsible by the safe operation of the detector. All actions initiated by the operator and all errors, warnings, and alarms concerning the hardware of the detector are handled by the DCS [3].

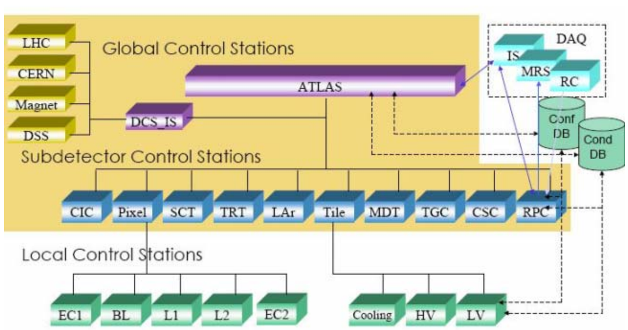

Figure 1: Hierarchical organization of the ATLAS DCS Back-End system

The DCS architecture consists of a distributed Back-End (BE) system running on PC's and different Front-End (FE) systems. The functionality of the back end software is two-fold. It acquires data from the FE equipment and it offers supervisory control functions, such as data processing and analysis, display, storage or archiving. It also provides handling of commands, messages and alarms. In order to provide the required functionality, the BE system of the ATLAS DCS is organized hierarchically in three layers or levels as shown in figure 1. This hierarchy allows the experiment to be divided in independent partitions which have the ability to operate in standalone or integrated mode.

The TILECAL main DCS systems control and monitor the Low Voltage (LV) power system, the High Voltage (HV) system and the cooling of the electronics. Other control systems exist for the calibration related systems: cesium calibration source, minimum bias events monitoring and laser monitoring. The calibration related systems will have their own control systems, independent of DCS, but will exchange data and commands with the TILECAL DCS. In 2005 the TILECAL started the insertion of the LV power supplies in the modules inside the ATLAS cavern. In order to ensure a good performance of the detector a set of commissioning tests was prepared. For this phase a standalone control system was implemented. This allowed testing the integration of the several different subsystems namely cooling, HV and LV.

SYSTEM TOPOLOGY

The logical structure of the TILECAL DCS is subdivided in blocks, attending to functional criteria, and structured in a tree-like way in order to give to the user a better view of the control system. All functional blocks can run autonomously. The system comprises the following blocks:

- High Voltage system: required for the operation of the PMT's
- Low Voltage system: required for a proper operation of all the readout electronics and for the HV regulation
- Cooling system: monitoring and control of the TILECAL sector of the ATLAS central Cooling, to keep all the electronics inside the correct temperature range
- Stand alone systems: systems with their own control although interfaced with DCS for data exchange in order to guarantee the safe operation of the detector. This is the case of the calibration systems using a Cesium source a Laser system and Minimum Bias events.

The TILECAL DCS will be divided in four sectors all identical from the logical point of view, two for the extended barrel regions and two for the central region. Each sector is composed of one Cooling, HV and LV partition. The hierarchy of PC's in TILECAL includes

only 2 layers, a top layer with the TILECAL Control Station,
and a bottom layer with 4 Local Control Stations (LCS), one per sector.

SOFTWARE

Supervisory Control and Data Acquisition (SCADA) systems are software commercial packages normally used for the supervision of industrial installations. Their role is to gather information from the front end electronics, process the data and present it to operator. The usual functionalities include human-machine interface, alarm handling, archiving, trending, access control, etc, and also sets of interfaces to hardware and software. SCADA products provide a standard framework for developing applications and lead in this way to a homogenous control system.

A major evaluation of SCADA products was performed [4], which concluded with the selection of the PVSS from the Austrian company ETM. This product is now intensively used in the four LHC experiments at CERN.

For field bus communication TILECAL DCS makes use of the Controller Area Network (CAN) based protocol CANopen. For this a dedicated Open Protocol Communication (OPC), CANopen server was developed by the ATLAS central DCS team. This server fulfils all the CANopen functionality required by the cards called Embedded Local Monitor Board (ELMB) [5], the core of the LV power supplies control and monitoring system. For storing the data, TILECAL DCS use the ORACLE databases provided by ATLAS.

TILECAL DCS MAIN SYSTEMS

A brief description of the most important TILECAL DCS systems is presented, giving emphasis on the performance of each system.

The High Voltage system

The TILECAL High Voltage system [6] is based on HV bulk power supplies located in crates that provide a common high voltage for each set of photomultipliers. For a common set of photomultipliers there is a regulator system (HVopto board) that provides fine adjustment of the voltage for each individual photomultiplier over a range of 350 V bellow the input voltage. Each two HVopto cards are controlled by another board called, HVmicro card. CANbus is used for the communication between the HVmicro cards and the PC equipped with Kvaser PCIcan cards. The communication with the bulk power supplies is done using RS422.

A PVSS API manager is still being developed for the control and monitoring of the high, with direct communication from the SCADA system in the PC HVmicro cards in the modules via CANbus, avoiding the middle layer based on a VME system that existed in the past prototypes. The HV system together with the LV is the most important system of the TILECAL DCS. The DCS besides ensuring the good behaviour of the HV system during operation is also responsible to read and store the applied voltages on the photomultipliers. In total, HV DCS will monitor more than 20000 parameters. Further, it needs to supply those values to the offline data reconstruction group. Photomultipliers gains can change with time and new calibration needs to be applied so it's necessary to store in database all the values set during the lifetime of the experiment.

A stability study performed in 2004 on 288 photomultipliers during 31 days, 3% of the total of the whole detector, showed that maximal fluctuations of the HV of a PMT during operation were of the order of 1 V.

The Low Voltage system

The low voltage system is composed by three devices: a low voltage power supplies (LVPS) located inside the "finger" region of modules of the calorimeter, auxiliary boards which power and control 4 LVPS and bulk power supplies providing 200V DC. The LVPS provide the voltage and current needed for the operation of the electronic boards inside the calorimeter. Each LVPS uses 200 V DC as input to supply eight voltages from 3.3V to ±15V with a maximum fluctuation of <1%. The control of the output levels is made by 4 channels 12 bit DAC's Maxim525. Power for the ELMB and respective motherboard comes from the Auxiliary boards. The Auxiliary boards are installed in crates far from the detector and they also allow switching on and off the output levels, and provide a clock for module synchronization.

The monitoring of both the LVPS and auxiliary board is provided by the ELMB's which also make the control of the Auxiliary boards. The DCS is responsible for the monitoring and control of all the system which has an total of more than 25000 monitored parameters.

Cooling system

The TILECAL cooling system operates with water at sub-atmospheric pressure using a so-called Leakless Cooling System. The system is controlled and monitored locally by a Programmable Logical Controller (PLC). The security and control of the system comes from the ATLAS Cooling central team which provides information to the users about there system. The TILECAL cooling system is composed by a cooling plant which cools, purifies and provides primary pressure to the water. The cooling plant supplies 24 individual sectors called cooling loops, 6 per TILECAL sector and each of those cooling loops has one regulator valve allowing them to be impendent of each other. The responsibilities of the TILECAL DCS are to monitor the temperate and pressure, of the cooling loops and at same time provide operational parameters. These parameters are the temperature and pressure for the whole plant and pressures for each the individual cooling loops.

Finite State Machine

The DCS Back-End in ATLAS is organized in three functional layers and the Finite State Machine (FSM) is the main tool for the implementation of the full control hierarchy. The detector is divided down into simple FSM units that are hierarchically controlled by other FMS's. This allows the control system to be divided in partitions that can be managed centrally or work independently in "stand alone" mode.

The Controls hierarchy and the Partitioning rules are implemented based on PVSS and State Management Interface (SMI). The object model in SMI is described using a dedicated language State Manager Language (SML).

PVSS tools are used to configure the system, to log and archive information and to provide User Interfaces. SMI++ tools are used to model Devices and Subsystem behaviour, to automate operations and to recover from error conditions.

The basic FSM elements are Device Unit (DU) and Control Unit (CU). The DU's provide the interface with the hardware while the CU's (with complex control programs) integrate the DU's on hierarchy. The TILECAL FSM, figure 2, will have over 21 control units and 600 device units.

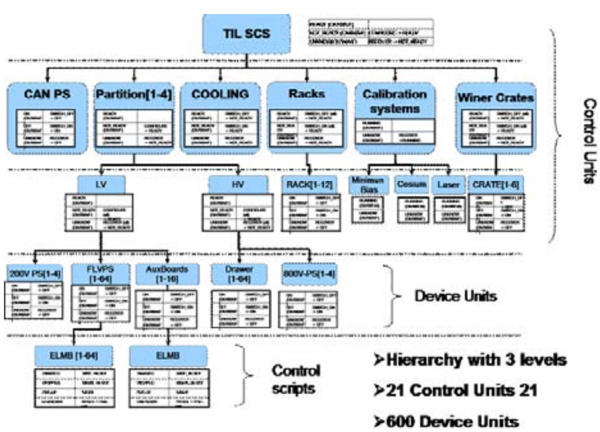

Figure 2: TILECAL FSM Architecture

Alarm Handling

At the ATLAS Global control Station level, there is also available an alert status. The alerts work independently of the FSM, however the status may be closely related. Automatic actions can also be triggered by alarms.

The alert panel has the following functionality:

- Display of alerts at supervisor level
- System names contain Data Point Element (DPE) this allows to track which sub-detector is giving the warning
- Alerts may have occurred at the Local Control Stations (LCS). For each hierarchy level there will be a display summary of alerts from the levels below.

Data Storing

The TILECAL DCS will use three types of database:

PVSS ORACLE archive: ORACLE database that stores relevant data for understand detector behaviour.

COOL Conditions Database: database which will store relevant data for offline data reconstruction in ATHENA [7].

Configuration Database: ORACLE database that will store system structure (lists and hierarchies of devices), device properties (like configuration of archiving, smoothing, etc.) and settings (like output values, alert limits).

The data produced by PVSS is stored in the DCS ORACLE archive, using a manager called RDB. Some of the data stored by DCS is useful for data offline reconstruction, like photomultipliers applied voltage, but the ATLAS software for data analysis, ATHENA, will not be able to read these ORACLE databases, so its necessary to make those data available outside ORACLE databases. For this purpose it was created the COOL database. COOL implements an interval of validity database, i.e. objects stored or referenced in COOL have an associated start and end time between which they are valid. COOL data is stored in folders, which are themselves arranged in a hierarchical structure.

The PVSS-COOL process takes selected data from the PVSS Oracle Archive and copies it into COOL, as shown in figure 3. During this process the datapoints types, representing devices, are associated with a folder, which will then allow the data from one or more of each device type to be stored into a folder.

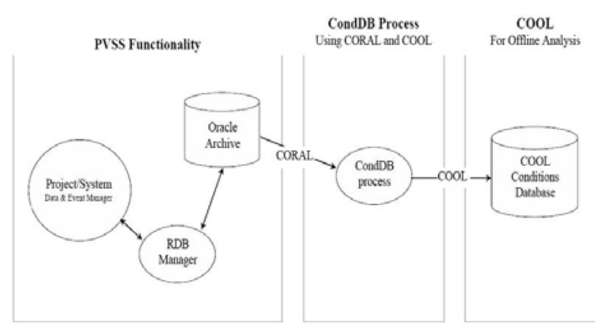

Figure 3: PVSS data flow

The amount of data produced by the TILECAL DCS is still under study but roughly TILECAL DCS will have around 3 kHz of readings during normal operation of detector. This will generate some hundreds of Giga Bytes of data per year which is more than acceptable for efficient operation. In order to reduce the amount of data stored a systematic study of the volume of data started and with an optimization of the parameters we decreased the volume by a factor of 10 to 300 Hz. In near future we hope to further increase this value to a factor of 2, ending with values to save into database at a rate around 150 Hz.

STATUS AND CONCLUSION

The calorimeter is installed in the cavern, and most of the DAQ and DCS electronics is installed. From the DCS point of view, TILECAL is divided in 4 partitions. The control system is already partially installed, with control and monitoring of low voltage for a fraction of 2 partitions, monitoring of the cooling system with connection to the cooling PLC, and a temporary prototype of the high voltage software.

The hierarchy of PC's includes only 2 layers, a top layer with the TILECAL Control Station, and a bottom layer with 4 Local Control Stations (LCS), one per partition. In this approach, each LCS has to run at least LV, HV, cooling and the respective FSM's. Such a system was never tested due to lack of hardware and software for a complete partition. The chosen PC's have Motherboard Intel ITSSE7520JR2-ATAD2, Xeon 3.0 GHz dual processor, 2 GB memory, and 3 PCI slots. The respective performance is expected to be enough for our system, but only after tests we will be able to tell if the respective performance is acceptable.

The most critical component until now was the low voltage system since several hardware problems were found during installation which lead a successively changing of the control program, namely with the start up procedure (switch on). This set of events leaded to a substantial improvement in the reliability of the DCS system due to intensive use and debugging.

Now DCS provides monitoring and control of the low voltage power supplies and auxiliary boards. For the 200V DC bulk power supplies, the first prototype was controlled and monitored using a serial interface RS422 but final production units arrived equipped with a serial Modbus interface. Since PVSS only provides a client for Ethernet Modbus, a RS422-Ethernet Modbus adapter needs to be used.

For the HV system the final project is still not complete and due to historical reasons, the current temporary prototype is based on drivers and PVSS managers that communicate via a shared memory. This complex system will be abandoned, giving room to software based on a Distributed Information Manager (DIM) [8] server. The DIM server was already made, and its basic functionality is being tested using the PVSS DIM client.

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