The ATLAS Tile Calorimeter DCS for Run 2

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Abstract—**TileCal is one of the ATLAS sub-detectors operating at the Large Hadron Collider (LHC), which is taking data since 2009. The Detector Control System (DCS) was developed to ensure the coherent and safe operation of the whole ATLAS detector. Seventy thousand (70000) parameters are used for control and monitoring purposes of TileCal, requiring an automated system. The TileCal DCS is mainly responsible for the control and monitoring of the high and low voltage systems but it also supervises the detector infrastructure (cooling and racks), calibration systems, data acquisition and safety. During the first period of data taking (Run 1, 2009-12) the TileCal DCS allowed a smooth detector operation and should continue to do so for the second period (Run 2) that started in 2015. The TileCal DCS was updated in order to cope with the hardware and software requirements for Run 2 operation. These updates followed the general ATLAS guidelines on the software and hardware upgrade but also the new requirements from the TileCal detector. A report on the upgrade and status of the TileCal DCS system will be presented.**

Index Terms—**ATLAS, TileCal, DCS, WinCC.**

I. INTRODUCTION

THe Large Hadron Collider (LHC) [1] is part of the accelerators complex at CERN. It is currently providing high energy proton-proton and heavy ion (lead) collisions at energies of 13 TeV and 5.02 TeV respectively, having achieved a peak luminosity of $1.37\text{x}10^{34}$ cm^{-2} s^{-1}. Collisions are available at four points of the LHC tunnel, where the main LHC experiments (ALICE, ATLAS, CMS and LHCb) are installed. ATLAS [2] is a general purpose experiment being composed of different sub-detectors positioned in layers around the collision point having a rich physics program which goes from Higgs Boson to SUSY, extra dimensions, dark matter and more. TileCal (or Tile Calorimeter) is the ATLAS hadronic calorimeter [3] located in the central region. The calorimeter uses steel plates as passive absorber and scintillating tiles as active material. These are read by photomultiplier tubes (PMTs) using wavelength shifting optical fibers. The detector consists of three sections, two extended barrels (EBs) and a long central barrel (LB) divided in two partitions for operational purposes. Each partition is divided in 64 modules and each module holds its own Front End (FE) electronics. The FE electronics is located in the outer side of each module and is composed of a Finger Low Voltage Power Supply (fLVPS) and a so-called super-drawer which holds the PMT High Voltage (HV) distribution system and FE electronics dedicated to the physics data acquisition. The TileCal DCS monitors continuously hardware parameters such as temperatures and voltages and is the main responsible for the operation of the detector electronics and its infrastructure. Furthermore the TileCal DCS performs the actions required by the operator and provides alerts in case of hardware malfunction, as well as it takes automatic preventive actions in some defined situations. Finally, it should also provide sufficient data resources to the experts when debugging the system. During the Long Shutdown 1 (LS1) in the years from 2013 up to the beginning of 2015, TileCal went through a huge operation of consolidation and maintenance of its FE and BE electronics, readout and calibration systems. In parallel to these activities, the DCS was upgraded for a new software version and new control components have been added.

II. OVERVIEW OF TILECAL DCS DURING RUN 1

A. DCS structure and monitoring software

The Back-End (BE) of TileCal DCS [4] [5] follows the ATLAS DCS [6] structure and is organized in three operational layers as can be seen in Fig.1. At the bottom level it has four similar Local Control Stations (LCS), each of them responsible for the monitoring and control of the electronics associated with one TileCal partition. The ”Tile Calorimeter” Sub-detector Control Station (SCS), Fig.1, brings together the controls of each LCS and integrates the DCS of TileCal into the ATLAS DCS. It also monitors the Laser system and other components related with the detector's infrastructure. The TileCal DCS is based on a commercial Supervisory Control and Data Acquisition (SCADA) tool ProzessVisualisierungs und Steuerungs System (PVSS) which was chosen by the Joint COntrols Project (JCOP) framework [7] at CERN. The core of the DCS software is organized in a so-called project. A project is composed of Datapoint (DP) elements that describe the hardware in terms of its monitored data and runs a set of managers (processes) which can be of different types such as Remote Database, Distribution manager, Control Managers, among others. To ease the effort and developing time of a new control system component, software and tools were provided by JCOP framework and ATLAS DCS. To communicate and exchange data with the electronics or other systems, the DCS makes usage of OLE for Process Control (OPC), Distribution Information Management (DIM) [8] and MODbus. The JCOP Finite State Machine (FSM) toolkit [9] is used to model and implement the DCS BE hierarchy. The commands from higher levels are propagated downwards to the individual devices where they are executed accordingly to a list of programmed actions. A set of conditions determine the State and Status of each device which are propagated upwards in the hierarchy. The FSM is the most used interface to operate the detector electronics and infrastructure.

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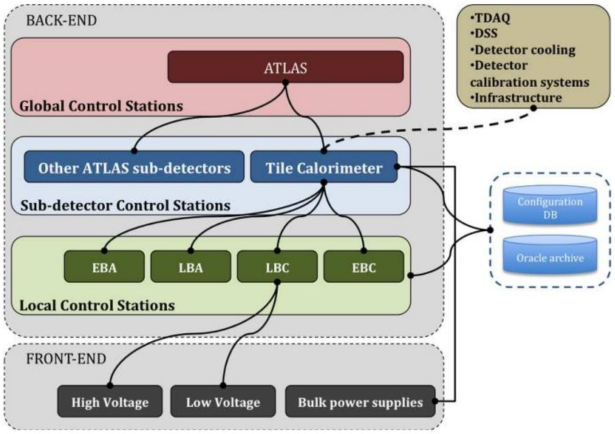


Fig. 1. TileCal DCS hierarchy as part of ATLAS DCS in Run 1 (image adapted from [5])

B. Hardware supervised by DCS

A brief description of the detector hardware controlled and monitored by TileCal DCS is given in this section.

1) Tesla 200V DC Power Supply: Custom designed 200V power supplies produced by Tesla were used during the Run 1. They were installed in racks in the ATLAS USA15 cavern. Each of these power supplies had 3 independent channels and each channel provided 200V for the FE electronics of the 4 modules.

2) Finger Low voltage Power Supplies: The finger Low Voltage Power Supply (fLVPS) is composed of monitoring boards and 8 individual DC-DC converters (bricks). The fLVPS is responsible for the conversion of 200 V DC into 8 different voltages in the range from -15V to +15V. The monitoring of fLVPS is based on Embedded Local Monitoring Boards (ELMB) [10] and the communication with the ELMBs uses an OPC Data Access (OPC DA) running in the Windows host using the CANOpen protocol over CANbus.

3) Auxiliary Board: Auxiliary boards (AUXBoard) are used in the control of fLVPS providing the power for the ELMB and the current loops which enable or disable the fLVPS outputs. Each AUXboard provides independent control of four fLVPS. The communication with the AUXboard is based on the ELMB and uses the same OPC DA as fLVPS.

4) Tesla 830/950V DC: The Tesla 830/950V DC High Voltage Power Supply is the primary source of the HV for TileCal and each crate holds 16 individual HV channels that provide HV for 16 modules. The control and monitoring of these crates is based on RS422 standard and uses a TPC/IP gateway as interface between the control system and the crate controller.

5) Front-End HV distribution System: The FE HV distribution system regulates the input HV (830 or 950VDC) into 48 individual voltages, one per photo-multiplier tube (PMT). The system is composed of the controller board (HV-Micro) and the distribution boards (HV-Opto) [11]. Besides the regulation and readout of the HV applied to the PMTs, the system also monitors the temperatures and the low voltage necessary to the operation of the boards. The communication with the HV-Micro boards is done via CANbus using a custom made protocol.

6) VME Crates: Tile Calorimeter uses commercial VME crates for powering and housing the VME-based boards. The monitoring and control of the crates is performed over CANbus and the interface between the SCADA tool and the crates rely on the OPC DA server.

7) CANbus Power supplies: There are two types of CANbus Power Supplies (CAN PSU), one for the devices where the monitoring is based on ELMB (LV CAN PSU) and the other for HV-Micro cards (HV CAN PSU). The communication and control of the LV and HV CAN PSU is based on the ELMB and HV-Micro card respectively. The LV CAN PSU makes use of the same OPC DA server as the fLVPS and AUXboard. The HV-Micro inside HV CAN PSU uses a different firmware from the one used in the FE HV distribution system and therefore a different protocol and a DIM based server is used.

8) Cooling System: The cooling of the FE electronics is achieved by a dedicated cooling system working at sub-atmospheric pressure. A cooling station supplies 24 cooling loops, each of them individually regulated. The overall control of the cooling system is based on a Programmable Logical Circuit (PLC) which exchanges operational data with the DCS (temperatures, pressures, pump power consumption). The data from the PLC is transmitted to DCS via MODbus over TCP/IP.

9) Laser system: TileCal makes use of different calibration systems [12] to monitor and calibrate the readout system. The Laser system is one of these calibration systems and is used to monitor the stability of the PMT signals which can be affected by radiation, temperature and drift of PMT's applied HV. The interface of the Laser system with DCS is implemented using a DIM based server (Windows) over TCP/IP.

C. Exchange of data with the Data Acquisition system

DCS can receive inputs from the Data Acquisition (DAQ) system and trigger actions in the electronics, if required. The associated software is based on the data exchange between DCS and DAQ via DIM. Nevertheless, some of the data sent by the DAQ can trigger actions on the hardware, such as power-cycle of the FE electronics, change of HV settings in one or more PMTs and power-cycle/reset of the VME crates. DCS also receives data which do not trigger any action, such as run number and type (physics or calibration) which DCS records and uses in automatic electronic reports (Elogs). During run time, DCS sends information about the status of the FE electronics to the DAQ system.

D. Automatic Procedures

Based on the monitored data, the DCS is able to recognize specific hardware malfunctions and automatically executes actions to recover them. The DCS of TileCal implements two types of automatic actions - the recovery of an abnormal shutdown (trip) of a fLVPS and the switch off of a device or full detector. The fLVPS trip recovery procedure is executed when the DCS detects an abnormal output voltage from one or more fLVPS bricks. The procedure executes a full shutdown of the affected module restarting it immediately after. The switch

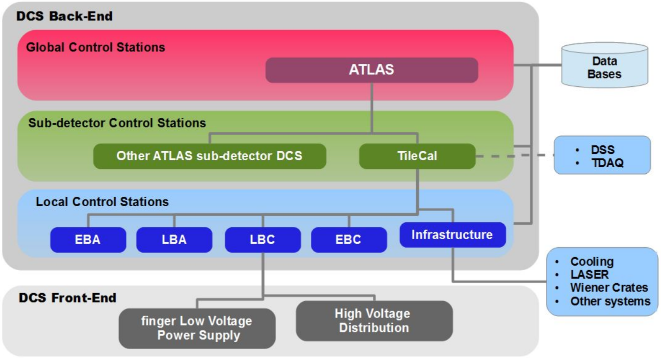


Fig. 2. TileCal DCS hierarchy for Run 2

off of a device (for example an AUXboard) is performed in case the measured temperature is above the safety limit. The detector switch off can be triggered by Detector Safety System (DSS) in case of a major problem with TileCal cooling plant.

III. UPGRADE OF DCS DURING LS1

A. Software

The main guideline of the ATLAS DCS upgrade for Run 2 was the migration of the DCS from Windows to Linux operating system. The PC hosts were installed with the CERN Scientific Linux 6 and the latest version of PVSS, which was re-branded to WinCC Open Architecture (OA) (further on WinCC). The migration from Windows to Linux drove the replacement of the OPCs DA used during Run 1, by new OPC Unified Architecture (OPC UA) [13]. The OPC UA is slimmer, multi-platform and the source code is available.

B. DCS Back-End structure

To improve the uniformity of the DCS BE, the old ”TileCalorimeter” SCS (Fig.1) was divided into two separate control stations. The control components related with infrastructure, cooling and Laser monitoring were moved to a dedicated project called Infrastructure. With this restructure the new TileCal project combines the monitoring of all the projects and integrates the TileCal DCS in the ATLAS DCS. The new DCS schema can be seen in Fig.2.

With the new configuration of the SCS and ”Infrastructure” projects, new FSMs were built, keeping the overall FSM hierarchy from Run 1.

C. Control system for new 200V Power Supply

To prevent hardware failures a commercial power supply (PS) from the TDK company was selected to replace the existing TESLA 200V DC. It was chosen a single channel 200V power supply with a maximum output of 2.4kW, which allowed to keep an identical granularity of one individual power supply per 4-modules and additionally facilitate its replacement in case of failure. To integrate the new 200V PS in the existing DCS, a new control system was implemented. The control system was developed using WinCC and is based on the RS232 communication standard. The physical interface with the devices is made through the serial port of the local server. The 64 power supplies are arranged in four daisy-chains in groups of 16 units (one chain per TileCal partition). The new system was integrated and merged with the existing 200V PS DCS system being prepared to allow an easy switch between the old and new 200V PS during the commissioning time of the detector in LS1. From the point of view of the communications, the new control component is simpler since it does not require an extra TPC/IP gateway neither an extra script to validate data arriving to WinCC. The update of the monitored data is also faster. It is done every 6s now, while it was done every 20s [14] in the previous system. An example of the monitored data by the new control system can be seen in Fig.3.

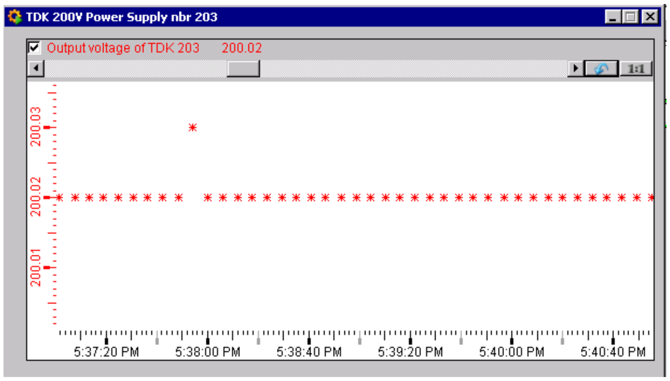


Fig. 3. Readings of the output voltage of a 200 TDK power supply acquired by DCS over time. In the plot is visible the regularity of the readings over time and it is also visible a maximum fluctuation of 0.01V in one of the readings

D. Control System Upgrade for HV-Micro

The HV-Micro is the controller and monitoring board used in the FE of the HV distribution system and in the HV CANbus PS. The DIM servers used in Run 1 were replaced by an OPC UA built in collaboration with the ATLAS DCS using the tool QUASAR [15]. The OPC UA server implements the two different custom made protocols to communicate with the two types of HV-Micro, reducing the amount of code to maintain. Along with the development of the OPC UA, the internal structure and procedures used inside the control system that supervises both types of hardware components had to be modified to reflect the changes. One of the most notable features which was made possible with this modification is the one-bit quality factor of the data (data is marked as invalid when the hardware does not reply). With the DIM server it was a complicated task to determine if the loss of the monitoring was originated from software problem (crash of the server) or hardware problems. Now, when the data is marked as invalid this is an indication that the OPC server is operating well but there is no reply from the hardware device.

E. Devices with control based on ELMB

The control system components based on the ELMB as a general purpose I/O unit were updated to work with OPC

UA. The ELMB is mainly supported by the ATLAS DCS team, who developed and provided the OPC UA server and the tools (framework components) to convert the supported functionalities from OPC DA to OPC UA. Nevertheless, the control of the fLVPS and AUXBoards have some required customization in the ELMB usage, which was taken care by the Tile DCS. The LV CAN PSU migration from OPC DA to UA server was easier and did not require any additional code.

F. Wiener VME crate control

With the upgrade of the Wiener crate middleware the monitoring of the voltages and currents provided by the crates was also included. During the LS1 two additional crates for the Tile-Muon Digitizer Boards (TMDB)[16] were installed in the ATLAS USA15 cavern. The TMDB crates and the monitoring of the output voltages and currents of the crates channels were added to the existing control system using the JCOP framework tools for this common hardware. The final step in the upgrade of this system was the conversion to the OPC UA. The UA server and the conversion tool were provided by the ATLAS DCS and the modification to the new middleware was straightforward.

G. Upgrade of the Laser system - LaserII

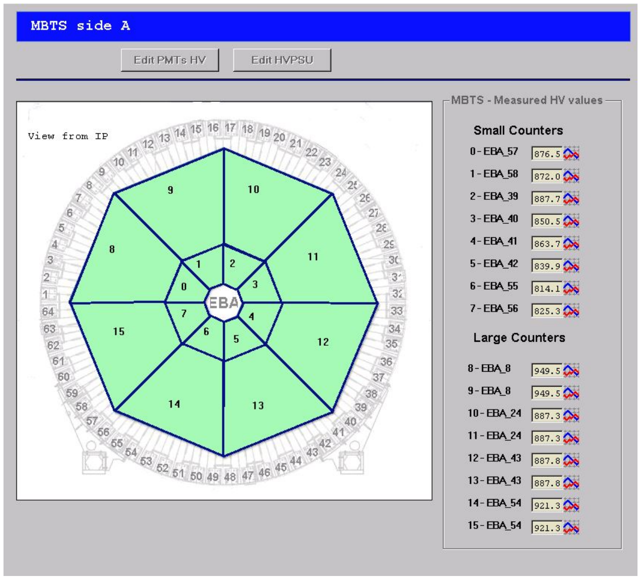
To cope with the aging of the old system [17] and to reach the sub-percent level in the monitoring of the PMT response [18] an upgraded version of the Laser system was developed and installed in late 2014. Since the existing DCS Laser component was not compatible with the LaserII, it was required to develop a new one. A new DIM-based server running in Linux implements a custom made protocol over TCP/IP operating as middleware between LaserII boards and the new parameters in WinCC. A new FSM branch was developed implementing the state and status conditions of the boards and integrated within the TileCal DCS FSM at the level of infrastructure. The actual and historical monitored data of the LaserII is available for users through the new FSM user interfaces.

H. MBTS and gap/crack scintillators

The Minimum Bias Trigger Scintillators (MBTS) and the gap and crack scintillators are located outside of TileCal barrel structure, and are sampled by dedicated PMTs located inside the EB partitions. A procedure based on the partition and scintillator type was implemented for verification or change of the applied voltage on those PMTs reducing the human time and effort required. An example of the FSM interface for MBTS, is shown in Fig.4.

IV. OPERATIONAL EXPERIENCE

The outcome of the Run 2 experience with the upgraded TileCal DCS is positive. When required, the update of the OPC UA servers is performed with a minimal downtime of the affected part. The HV-Micro OPC is much more stable and free of crashes which were observed sometimes in the old DIM based server used for the FE HV distribution system. Since the beginning of the Run 2 there was no need to restart an OPC server due to malfunction of any type. Presence of the quality factor in the data arriving from the FE HV distribution system proved to be very useful during operation. As an example, the interruption of communication (pink square) shown in Fig.5 would pass unnoticed with the DIM server version. The control system of the TDK 200V PS is simpler and more reliable than the previous version. The new project structure allows changes at the level of ”Infrastructure” LCS such as modification of the FSM components, with a minimal impact and without disturbing the functionality of the top and partition levels of the TileCal FSM.



Small Counters

0 - EBA_57 876.5
1 - EBA_58 872.0
2 - EBA_39 887.7
3 - EBA_40 850.5
4 - EBA_41 863.7
5 - EBA_42 839.9
6 - EBA_55 814.1
7 - EBA_56 825.3

Large Counters

8 - EBA_8 949.5
9 - EBA_8 949.5
10 - EBA_24 887.3
11 - EBA_24 887.3
12 - EBA_43 887.8
13 - EBA_43 887.8
14 - EBA_54 921.3
15 - EBA_54 921.3

Fig. 4. Example of one FSM user interface for MBTS in EBA. On the right is displayed the applied voltage to each of the dedicated PMTs. The scintillating light of the 8 larger counters are combined in 4 groups of 2 scintillators, being each group read by the same PMT.

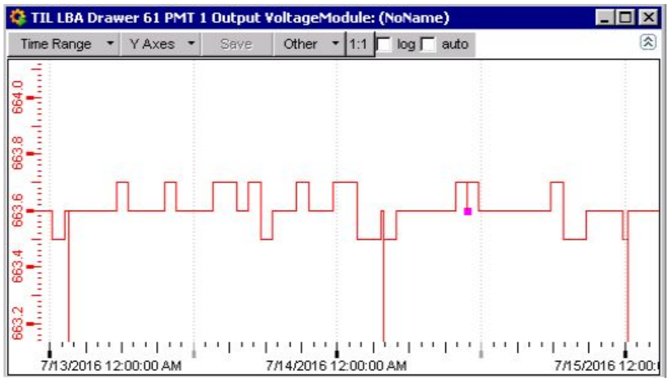


Fig. 5. Monitored High Voltage applied to one PMT over time. The pink square point mark the time when the monitored data is invalid.

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V. FUTURE PERSPECTIVES FOR THE TILECAL DCS

To cope with the increase of luminosity delivered by the LHC, the TileCal community is developing and testing new FE and BE electronics [19] [20] for physics data and controls. These replacements will require new control blocks from DCS such as blocks for new HV distribution system and for a new fLVPS concept.

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