The TILECAL/ATLAS Detector Control System

J. Pina on behalf of the Tilecal subsystem of the ATLAS collaboration

***Abstract*— Tilecal is the barrel hadronic calorimeter of the ATLAS detector that is presently being built at CERN to operate at the LHC accelerator. 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. The DCS has to continuously monitor all operational parameters, give warnings and alarms concerning the hardware of the detector. The DCS architecture consists of a distributed Back-End (BE) system running on PC's and different Front-End (FE) systems. The implementation of the BE will be achieved with a commercial Supervisory Control And Data Acquisition system (SCADA) and the FE instrumentation will consist on a wide variety of equipment. The connection between the FE and BE is provided by fieldbus or LAN and a SCADA Real-Time (RT) database will contain records of all equipment and where the corresponding data values are stored. The Tilecal DCS design is being finalized. Prototypes of the main systems were already tested and are being upgraded to be used in the 2004 ATLAS subdetectors combined testbeam at CERN. The low voltage control system is based on the ELMB board developed by ATLAS for the several subdetectors and the high voltage system is based on the HV-micro boards developed by Tilecal. Status and results are presented.**

***Index Terms*— Detector Control System, Calorimetry**

I. INTRODUCTION

Tilecal is the barrel hadron calorimeter of the ATLAS detector [1], [2]. It is a sampling calorimeter made of scintillating tiles readout by wavelength shifting fibres using iron as absorber and photomultipliers (PMTs) as photodetectors [3]. The PMTs and part of the front end electronics [4] are located in drawers that go inside the girder located in the outer side of the modules. Tilecal is composed of 3 cylinders, one central barrel covering the η region up to 1.0 and two extended barrels extending the η coverage up to 1.6. Each cylinder is composed of 64 modules. The principal task of the 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 the DCS [5].

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 DCS is organized hierarchically in three levels as shown in figure 1. This hierarchy allows the experiment to be divided into independent partitions which have the ability to operate in standalone or integrated mode.

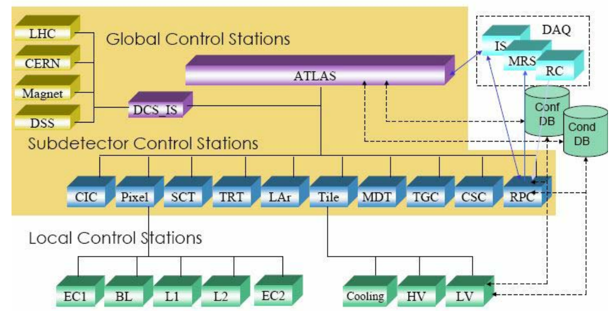

Fig. 1. Hierarchical organization of the ATLAS DCS Back-End system

The Global Control Stations (GCSs) permit overall operation of the detector, and the lower levels have the responsibility of data processing and execution of commands. Archiving, alarms and logging of commands and incidents are provided at every level.

The Tilecal main DCS systems control and monitor the low voltage power supplies (LVPS), the high voltage (HV) 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. There is a close interaction with the DAQ system, and the synchronization between the DAQ and DCS is essential to produce good quality physics data.

II. SOFTWARE

SCADA (supervisory control and data acquisition) systems are commercial software 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 the operator. The usual functionalities include human-machine interface, alarm handling, archiving, trending, access control, etc, and also sets of interfaces to hardware and to software. SCADA products provide a standard framework for developing applications and lead in this way to a homogeneous DCS.

A major evaluation of SCADA products was performed at CERN in the framework of JCOP [6], which concluded with the selection of PVSS-II from the austrian company ETM. This

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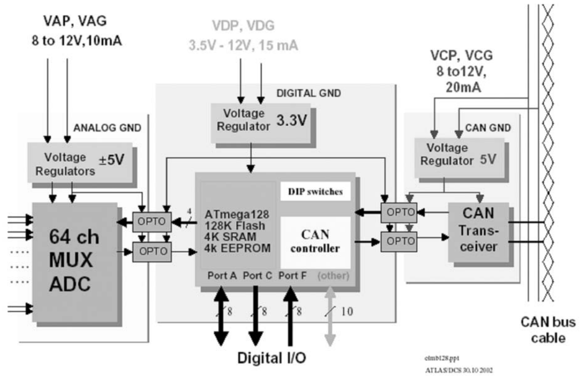

Fig. 2. Block diagram of the Embedded Local Monitor Board (ELMB)

product will be used for the implementation of the back end systems of the four LHC experiments.

An OPC CANopen server that fulfills all the CANopen functionality required by the ELMB (see section III) was also developed by the ATLAS central DCS team and is used by the Tilecal DCS to connect the ELMBs to PVSS-II.

III. ELMB

A versatile general purpose, low cost and low power consuming, electronics module called Embedded Local Monitor Board [9] (ELMB) has been developed by the ATLAS DCS team for standard analog and digital input/output. The respective block diagram is shown in Fig. 2. The ELMB was designed to operate in the hostile environment of the ATLAS cavern (radiation, magnetic field). Results for the 2003 [7], [8] prototype proven that the ELMB operates to about 140 Gy and 5.3×10^{12} neutrons cm^{-2} and operates in magnetic field up to 2 T.

The ELMB has 64 high precision analog input channels of 16 bit accuracy. Its serial port can drive additional devices like a digital to analog converter (DAC). The firmware includes instructions for both driving the input/output functions and the communication over the CAN fieldbus using the CANopen protocol.

IV. New radiation tests

In 2004 the TILECAL group made a new radiation test, to test the mass production series of the ELMB and also the new motherboard and DAC's for the low voltage power supplies. The irradiation was performed in May of 2004 in a low energy Proton Irradiation Facility (PIF) at the Paul Scherrer Institute (PSI), Villingen Switzerland. Both ELMB and Low Voltage Power Supply motherboard where irradiated with 60 MeV protons with fluence up to $5 \times 10^{8} cm^{-2}$. This corresponds to a Total Ionizing Dose (TID) of 190 Gy.

The 4 ELMB and 4 motherboards were irradiated successively. Both ELMB and motherboard where irradiated simultaneously in steps of 50 Gy from 50 to 250 Gy. The setup used consisted on a motherboard with an ELMB and DAC fixed in the frame perpendicularly with the beam.

TABLE I

Number of software SEE for each means of recovery

Recovery	Number of SEEs detected for 5.3×10^{11} protons cm^{-2}	average fluence (for 1 error)
Power cycling	1	5.3×10^{11}
Software reset	0	$> 5.3 \times 10^{11}$
Automatic recovery	2	2.65×10^{11}
All types of recovery	3	1.76×10^{11}

A total of 14 analog input channels of the ELMB connected to 8 DAC outputs, 2 thermistors temperatures and 4 DC constant voltages where monitored each 10 seconds. Voltages and currents of two power supplies, one for CAN and the other for the ELMB, where also monitored via GPIB each 10 seconds. The monitoring of the CAN messages was performed using 2 different programs: Winhost to analyze all CAN messages in the bus and PVSS to monitor, control and collect data.

For the motherboard tests 8 DAC channels (2 DAC chips - Max525 from Maxim) were monitored, 6 with variable values and one per chip, with an constant value over all irradiation. The DAC output channels were connected in parallel to the ELMB ADC and to GPIB. The reading of all the parameters was also performed at intervals of 10 seconds.

For the ADC of the ELMB, three functional misbehaviours were detected up to 190 Gy (table I). They are divided in 3 categories, according to their normal behaviour. It was also detected an increase in the ELMB current but the current was still within acceptable values at the end of irradiation. For the 4 motherboard tested, no SEE effect was observed in the DACs and it was not detected any increase in the current.

With these results we can say that the ELMBs are ready for operation for 10 years under the radiation environment of TILECAL, with a safety factor of 70 included.

V. Low voltage system

The low voltage power supplies for the Tilecal calorimeter are being developed by the collaboration. These LVPS will be located inside the fingers at the extremities of the girder of the modules and have to provide a total of 8 different voltages to the drawer front end electronics, three for the high voltage system (HV-15, HV+5, HV+15) and five for the motherboard and digitizers (MB-5, MB+5, MB+15, DIG+5, DIG+3.3). The units that produce these individual voltages are called bricks, and each LVPS contains 8 bricks.

A. LVPS control and monitoring

The voltages and currents are monitorized using ELMBs. Custom made motherboards for the ELMBs were designed for the Tilecal LVPS and one can be seen in the photo of Fig. 3 with the ELMB on the top of it. These motherboards also hold the 4 channels 12 bit DACs Maxim525 used to control the voltage output levels of the bricks. The Tilecal LVPS were designed to fit inside the so-called fingers that exist at the extremities of the girders of the Tilecal modules. To provide power for the

ELMBs and respective motherboards, special auxiliary boards were designed. These auxiliary boards are installed in VME crates and provide power for the digital and analog circuits of the ELMBs and for the respective motherboards, allow the switch on/off of the HV and MB/DIG low voltages, and provide a clock for synchronization of the modules. One auxiliary board powers 4 LVPS units.

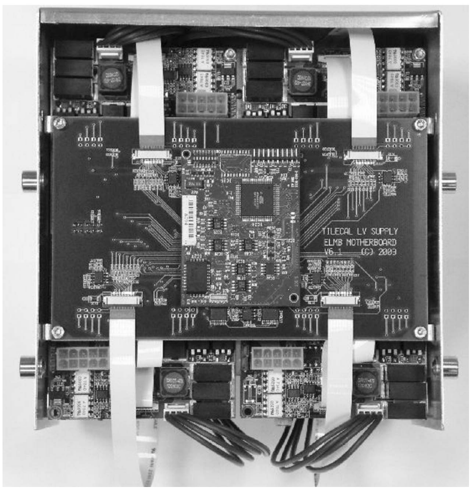

Fig. 3. Top view of one LVPS showing the motherboard with the ELMB card (dimensions 5 x 7 cm^2) at the center on the top of the motherboard.

VI. 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 using Programmable Logical Controllers, and at the level of the Tilecal DCS there is only monitoring of the temperatures of the water that circulates in the electronics located inside the drawers (readout by the high voltage control system) and inside the LVPS units in the fingers (readout by the low voltage control system). At the testbeam there are also temperature probes at the exit and entrance of the cooling unit and of each drawer, monitored using one ELMB [10].

VII. HIGH VOLTAGE SYSTEM

The Tilecal high voltage system is based on HV bulk power supplies located in crates that provide a common input high voltage for each superdrawer. For each drawer there is a regulator system (HVopto card) that provides fine adjustment of the voltage for each individual PMT over a range of 350 V below the common input high voltage. One controller card HVmicro manages the two HVopto cards of the superdrawer. A PVSS-II API manager is being developed for the control and monitoring of the high voltage system, and CANbus is used for the communication between the HVmicro cards and the PC equipped with Kvaser PCIcan-Q cards. The communication with the bulk HV power supplies is done using RS422. In the past, there was a VME middle layer between the HVmicro cards and the SCADA system in the PC, but it was abandoned to make the system simpler, cheaper and easier to mantain. The VME based system was used in all the testbeams and is expected to be replaced during the current year, when the new prototype should be ready.

VIII. TILECAL DCS AT THE COMBINED ATLAS TESTBEAM

From March 2004 until November of 2004, a combined testbeam (CTB) with all subdetectors (trackers, calorimeters and muon system), representing a full slice of the ATLAS detector is taking place. The DCS for the tesbeam period aimed the integration of the different DCS subsystems; low voltage (LV), high voltage (HV), cooling system, scanning table and beam data. Another important aim during the combined testbeam was the integration of TILECAL DCS into the global ATLAS DCS hierarchy over a distributed system. This was fully achieved, and for that several software implementations were performed;

- Conditions Database,
  The condition database (conditionDB) prototype used is a class library, built on top of MySQL/DB to store and retrieve detector-related information with an associated ”validity-period”. The software integration was performed using the manager provided by the Lisbon conditions database team and some LV, HV and beam characteristics data were successfully stored in the database.
- Communication through DAQ via DDC (DAQ-DCS Communication) software
  The communication of the DCS with the DAQ system is done via dedicated software (DDC). For achieving a good communication and synchronization between both systems and at the same time maintain their independence the following types of information must be exchanged:
  - bi-directional data exchange like parameters and satus values
  - transmission of messages from DCS to DAQ, e.g. alarms and error messages
  - commands send by DAQ to DCS and feedback about their execution

  As these functions are independent the DDC software is composed by three independent components: the Data transfer (DDC-DT), the Message Transfer (DDC-MT), and Command Transfer (DDC-CT) component .
- Standard FSM (Finite State Machine)
  The Finite State Machine (FSM), is used to manage states. For the combined testbeam some standard FSM panels where implemented. The panels implemented allow to:
  - Display current state of machine
  - Display states of children
  - Allow for actions to be taken
- Alert status levels
  At the Global Control Station (GCS) level, there is also available an alert status. This alert panel has the following functionalities:

- Displays alerts at supervisor level
- System name shown in Data Point Element (DPE) name
  System names contain sub-detector name, so it is possible to detect which sub-detector is giving the warning
- Alerts may have occurred at Local Control Stations (LCS)
  For each hierarchy level there is a display summary of alerts from the levels below.

The alerts work independently of the FSM. However, the status may be closely related.

IX. Conclusions

The TILECAL DCS has been implemented by all the subsystems and it is working within the requirements. Almost all the components are fully tested and no major problems found until now.

During 2004 the combined ATLAS testbeam was prepared and implemented. The combined testbeam was an important achievement since this was the first opportunity to test all the DCS components in a distributed environment before starting the installation of DCS components in the ATLAS pit starting in 2005. In the testbeam all the components of the Tilecal DCS were successfully tested. The integration of the TILECAL within the ATLAS Global Control Station was also achieved and several software components were installed and tested.

During 2004 the new HV DCS prototype is being finalized and testes outside the testbeam already started. The new LVPS continued is tests and the DCS tests are expected to start in November. The new prototypes of power supplies for the CANbuses will also be tested during this period.

The work inside the ATLAS cavern will start also in next year, followed by commissioning of the system during 2005/6.

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