Detector Control System for the Electromagnetic Calorimeter in the CMS Experiment
Summary of the first operational experience

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Abstract

A full scale implementation of the Detector Control System (DCS) for the electromagnetic calorimeter (ECAL) in the Compact Muon Solenoid (CMS) experiment is presented.

The operational experience from the ECAL commissioning at the CMS experimental cavern and from the first ECAL and global CMS data taking runs is discussed and summarized.

I. Introduction

The CMS experiment is one of the two large multi-purpose detectors at CERN's Large Hadron Collider (LHC) [1]. CMS is currently installed at LHC's access point number 5 (P5) situated at Cessy (France) and is under final commissioning. One of the most accurate, distinctive and important detector systems of the CMS experiment is the high precision Electromagnetic Calorimeter (ECAL). It will provide measurements of electrons and photons with an excellent energy resolution (better than 0.5% at energies above 100 GeV [2]), and thus will be essential in the search for new physics, in particular for the postulated Higgs boson.

In order to successfully achieve these physics goals the ECAL collaboration has designed the calorimeter as a homogeneous hermetic detector based on 75848 Lead-tungstate ($PbWO_4$) scintillating crystals. Avalanche Photo Diodes (APD) and vacuum phototriodes (VPT) are used as photodetectors in the barrel part and in the end-cap parts of the detector, respectively [2]. All these components and front-end (FE) readout electronics inside the ECAL satisfy rigorous design requirements in terms of their response time (less than 25ns), signal-to-noise ratio, immunity to high values of the magnetic field induction (up to 3.8T in the barrel part of the ECAL) as well as in terms of radiation tolerance (expected equivalent doses of up to 5 kGy and neutron fluence of up to 10^{12} neutrons/cm^2) [2]. However, it has been shown that the light yield of $PbWO_4$ crystals and the amplification of the APDs are highly sensitive to temperature and bias voltage fluctuations [3, 4]. Therefore, the usage of these components has directly imposed challenging constraints on the design of the ECAL, such as the need for rigorous temperature and high voltage stability. At the same time, mechanisms that allow radiation to induce changes in crystal transparency (and hence in its response), imposed additional requirements for "in situ" monitoring of the crystal transparency [2]. For all these reasons specific ECAL sub-systems that provide the necessary services had to be designed. These include: Cooling system [5], High Voltage (HV) and Low Voltage (LV) systems [6,7], Detector Control Units (DCU), Precision Temperature Monitoring/Humidity Monitoring (PTM/HM)[8] and ECAL Safety System (ESS)[8]. In addition, a Supervisor application to summarize the status of all ECAL DCS subsystems was also implemented. The structure of ECAL DCS is summarized in Figure 1.

All ECAL DCS applications were developed in a SCADA (Supervisory Control and Data Acquisition) system called PVSS II (Prozess Visualisierungs und Steuerungs System)[9].

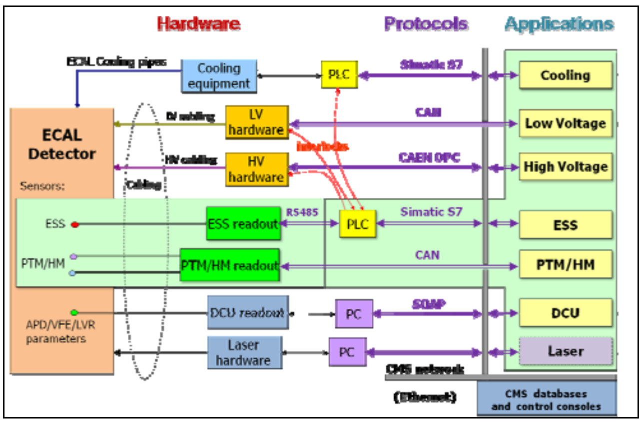

Figure 1: ECAL DCS layout

II. ECAL Supervisor

Implemented as a Finite State Machine (FSM) using the Joint Controls Project (JCOP) FSM component, the supervisor allows authorized users to issue commands and displays calculated states from all ECAL subsystems. Access control was implemented at all levels in order to prevent unauthorized use of the system.

Updates with new features and improvements are released regularly and so far problems concerning the application were observed only during installation processes. Figure 2 shows the main screen of ECAL Supervisor.

The main issue during commissioning, still under investigation, is related to the JCOP framework FSM blocking from time to time, which necessitates it being restarted.

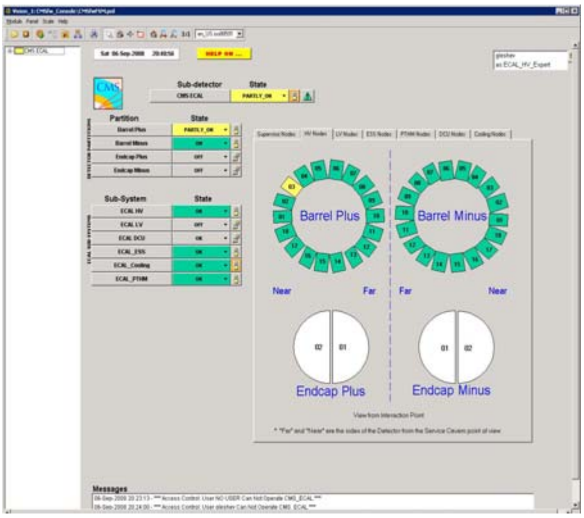

Figure 2: ECAL Supervisor main panel

III. ECAL COOLING CONTROL AND MONITORING

This has been implemented through the Unified Industrial Control System (UNICOS) framework, designed by CERN. The final hardware configuration consists of 72 pneumatic valves, 45 temperature PT100 sensors, 42 flow meters reading in magnetic field and radiation, 150kW heater powered by thyristors controlled by PID with PWM regulation.

The system has failsafe hardware interlocks connected to ESS with Supermodule(SM)/Dee granularity. The cooling PLC (Programmable Logic Controller) is monitored by ESS (watch-dog) as well.

Recently the regulation was tuned to +/- 0.02^{o}C at the detector input. A sample of regulation plots showing recent performance can be found in Figure 3.

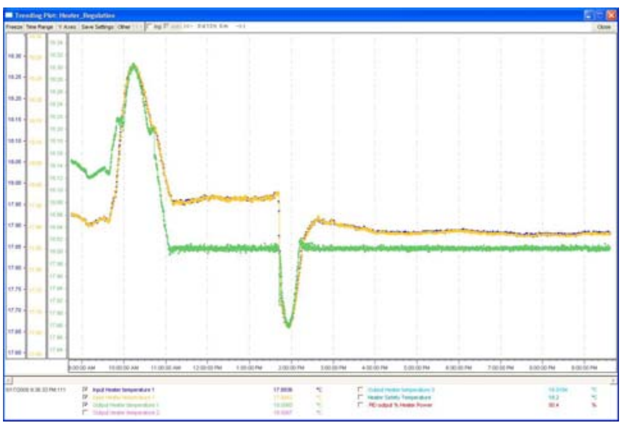

Figure 3: Cooling regulation (time x input and output temperatures)

During the initial phase of commissioning several problems were experienced related to the CMS primary cooling circuit, which caused interruptions on the ECAL cooling. Apart from that the system was always stable and reliable.

The development of the connection between the cooling control and the cooling monitoring system, developed as part of the ECAL DCS, is still ongoing.

IV. ECAL HV

Running on four computers in order to reduce the Central Processing Unit (CPU) load, the HV application is fully implemented to support ECAL. It controls CAEN crates, by switching ON/OFF specific sets of channels, configures output voltage setpoints with SM/Dee granularity and troubleshoots and monitors CAEN hardware.

Figure 4 shows the panel used to configure and monitor HV settings at the SM level.

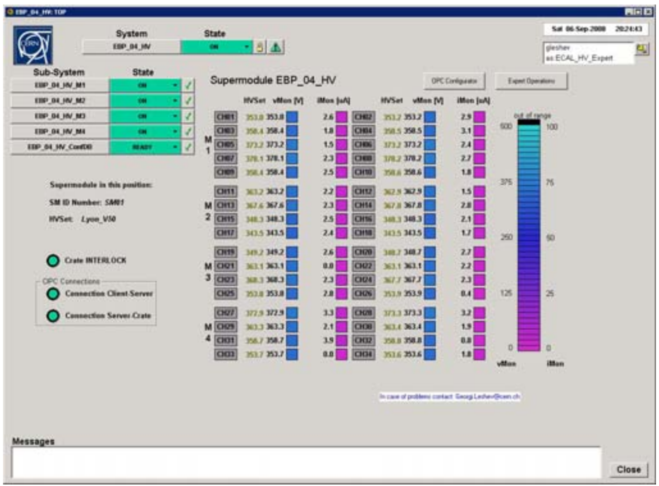

Figure 4: SM HV panel

The final configuration for the barrel hardware consists of 18 CAEN crates, with 8 boards per crate and 9 channels per board totalizing 1296 channels, from which 1224 are used. The endcaps hardware consists of 2 crates, with 2 boards per crate and 4 channels per board, totalizing 16 channels, all in use.

The power cuts were the main issue during commissioning and first runs, resulting in an average of up to 10 channels not working after each event. Part of the affected channels could be repaired, resulting in only 0.2 to 0.5% of unrecoverable channels from the total of 1240. It is very important to emphasise that all repairs were realized without delaying operations.

V. ECAL LV

Running on three computers (2 for the barrel and 1 for the endcaps) in order to reduce the CPU load, the LV application is fully implemented to support ECAL. It controls WIENER crates by configuring output voltage setpoints with SM/Dee granularity, troubleshoots and monitors the WIENER hardware.

The LV panel used to configure and monitor LV settings at the SM level is displayed in Figure 5.

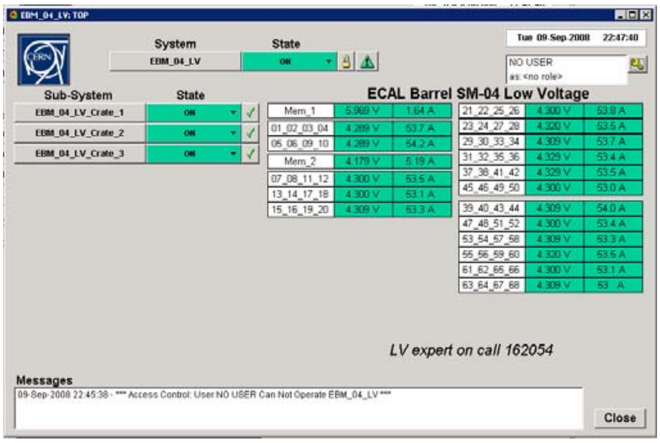

Figure 5: SM LV panel

The final barrel hardware configuration consists of 108 crates (3 crates per SM), with 6 to 7 channels per crate and 4 TT (trigger towers) per channel. The endcaps hardware consists of 28 crates (7 crates per Dee), with 6 to 7 channels per crate and 4 SC (super crystals) per channel. The total number of channels used for the LV system is 860, where 684 are for the barrel and 176 for the endcaps.

During the commissioning and first operations all hardware problems were fixed with minimum delay to the operations.

VI. ECAL DCU

DCUs are ADC based microcontroller chips used to monitor on-detector electronics; basically, they provide measurements of supply voltages, APD leakage currents and temperatures (more than 2000 parameters per SM/Dee).

The DCU readout is implemented via regular DAQ channels in a shared mode using dedicated timeslots for data transmission. All DCU data then goes directly to the CMS conditions database.

In order to have DCU data in DCS a software connection between DAQ and DCS has been implemented which is based on the JCOP PSX SOAP service (Figure 6).

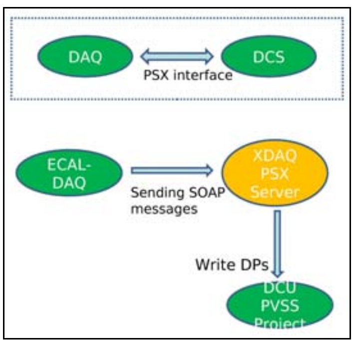

Figure 6: Software connection between DAQ and DCS

The biggest challenge for the DCU DCS application was to present in a compact way (Figure 7) an enormous amount of information (the DCU information volume is ~10 times bigger than the one of all other ECAL DCS subsystems). This was achieved based on the experience of the ECAL DAQ team in data quality monitoring (DQM).

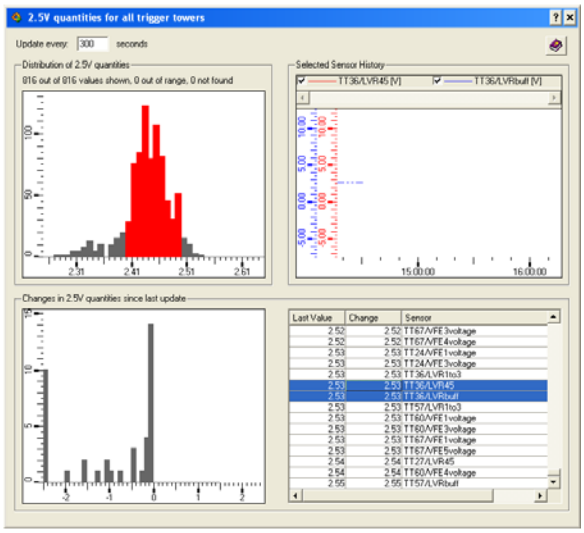

Figure 7: DCU panel

All problems during the commissioning phase, most of them concerning database access and configuration, were successfully solved.

VII. ECAL PTM/HM

This system monitors temperatures and humidity inside the ECAL detector (relative temperature measurement precision is approximately 0.01^{o}C, in order to monitor the cooling system and provide precise information for physics data processing). It is designed to have its own readout chain (probes, electronics, cabling and computing), completely separated from the ECAL DAQ readout. The PTM/HM provides non-stop monitoring even during CMS shutdowns.

Warnings and alarms are generated and propagated to the ECAL Supervisor to shutdown LV/HV, when over-temperature or high humidity conditions (SM/Dee granularity) are detected.

The application is about to be fully integrated into the CMS DCS and runs stable since the very beginning of operations in the CMS cavern.

During commissioning it became apparent that the temperature monitoring could be used to check the LV status of SMs and Dees by comparing the difference in temperature of the input and output water. This feature was implemented (Figure 8) and has been used as an extra resource by experts to support operations.

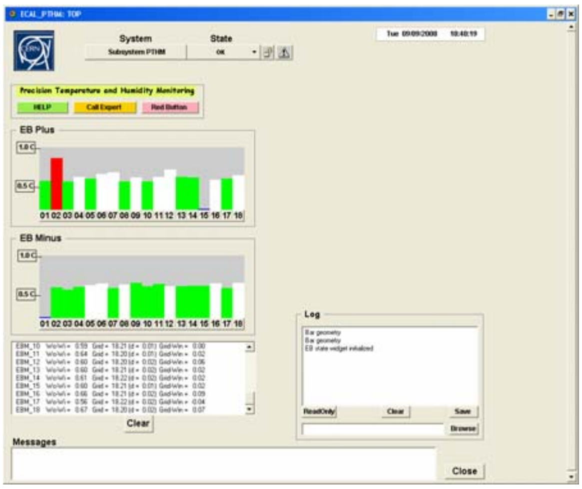

Figure 8: PTM/HM

The remaining relevant issues concerning this subsystem are the migration to the CMS conditions database, as at the moment all data is stored in local data files, and the design and implementation of further services for equipment trouble-shooting.

VIII. ECAL ESS

Designed to be fully autonomous and radiation tolerant[10], the ESS monitors the air temperature around the SM/Dees electronics with precision better than 0.1^{o}C, detects water leaks inside SM/Dees and in the LV racks and issues reliable interlocks to ECAL subsystems in case of unsafe conditions.

The panel displayed in Figure 9 shows all relevant parameters in a SM/endcap quadrant level, such as temperatures, warning and alarm levels, interlock status, as well as the ESS PLC and CMS Detector Safety System (DSS) status.

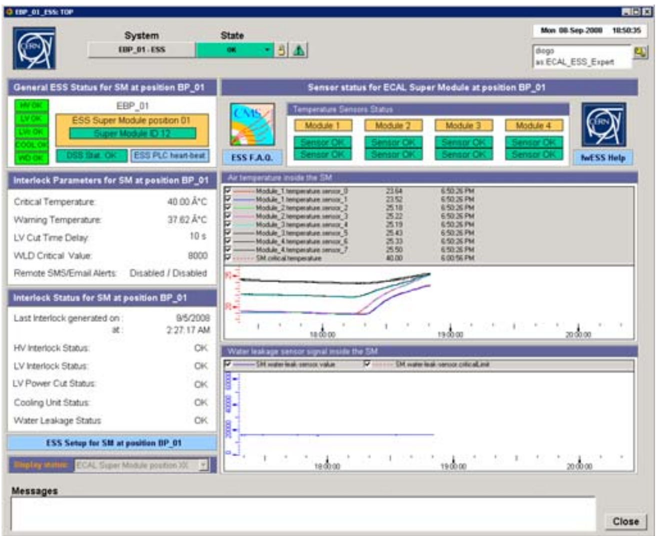

Figure 9: ESS SM panel

The most significant experience during one of the global runs was a problem related to the main power supply to the main UPS system, which triggered a CMS DSS shutdown signal to ESS. The safety system took correct actions by shutting down safely all ECAL subsystems.

Currently the main issue, still under investigation, is related to two Siemens communication modules CP 341 that became defective during commissioning.

IX. Conclusions

DCS has supported the entire ECAL (barrel and endcaps) since it has been installed and cabled. So far there were no periods of DCS unavailability and delays in the ECAL commissioning due to DCS related problems.

Power cuts were responsible for most of the problems concerning the hardware during commissioning and affected in general all subsystems. All problems induced by these events were handled in such a way that there was no significant interruption in ECAL operations.

The rather smooth DCS services extension in terms of scaling and functionality has been made possible due to several development workbenches, where applications could be tested before moving to the final system. However, it was not possible to reproduce the actual scale and exact configuration (CMS networks, database servers, etc) and therefore developers faced many challenges "in the field", such as considerable time spent to get the software interface DCS-DAQ running in stable manner and to provide a connection between the ECAL cooling system and DCS cooling monitoring application. The ECAL Supervisor was modified many times according to new demands from ECAL operation.

Summarizing, despite many obstacles and problems which seem natural for such a huge scale installation as CMS, ECAL DCS has demonstrated a reliable and always available support for ECAL commissioning and operation.

X. References

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