THE CMS ECAL DETECTOR CONTROL SYSTEM

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Abstract

The Compact Muon Solenoid (CMS) is one of the general purpose particle detectors at the Large Hadron Collider (LHC) at CERN. The challenging constraints on the design of one of its sub-detectors, the Electromagnetic Calorimeter (ECAL), imposed the development of a complex Detector Control System (DCS). In this paper the evolution of the CMS ECAL DCS during the period of commissioning and cosmic running will be presented. The acquired experience and feedback from operators were used to trigger several upgrades of the system's software in order to achieve a very robust, flexible and stable control system. A short description of the new features of all CMS ECAL DCS subsystems, including the relevant associated hardware, and their individual experiences will be discussed as well.

INTRODUCTION

The CMS ECAL [1] is sub-divided in three main parts: Barrel (EB), Endcaps (EE) and Preshower (ES). The Barrel consists of 36 Supermodules (SM) forming a cylinder around the interaction point. The EEs are the structures which close both ends of this cylinder and each of them is formed by two half disks named DEEs. The ES follows the EE's shape and is placed in front of it.

The ECAL DCS [1-3] responsibilities on the hardware side are limited to the ECAL Safety System (ESS) and to the Precision Temperature and Humidity Monitoring (PTHM). All remaining hardware is maintained by other ECAL groups and will not be discussed in this paper.

On the software side, the ECAL DCS responsibilities are extended to the full system, which consists of 11 components: Supervisor, Low Voltage (LV), High Voltage (HV), ESS Air Temperatures, ESS, PTHM, Detector Control Unit (DCU) Monitoring, Cooling Monitoring, Laser Monitoring, ECAL VME Crates Control and the ES Control and Monitoring. All these applications were implemented in PVSS II 3.x, a Supervisory Control and Data Acquisition (SCADA) software, using a two level access control (expert and operator) in order to restrict the access to parts of the system and in this way to guarantee a safe operation of the detector.

The simplified ECAL DCS block diagram is presented in Fig. 1.
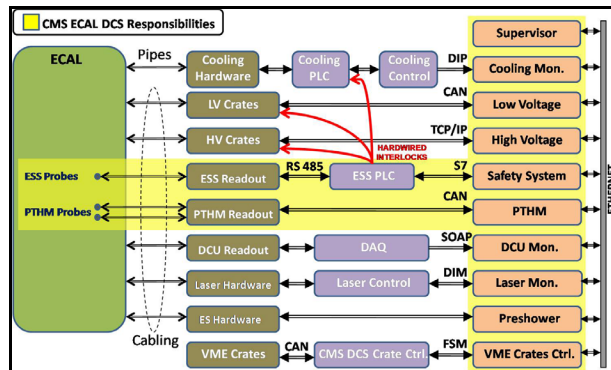

Figure 1: CMS ECAL DCS block diagram (simplified).

The ECAL DCS is fully integrated under the CMS DCS [1], with possibility to be operated either locally (by ECAL shifters) or centrally (by CMS shifters).

The period of commissioning and cosmic running was used by the ECAL DCS team to adjust the system under real conditions and to better understand the user's needs. According to their feedback, all software applications were constantly upgraded in order to move towards an optimal configuration.

THE CMS ECAL DCS SUBSYSTEMS

The Supervisor

The Supervisor was designed to connect all ECAL DCS subsystems and to centralize the control and the monitoring of all interactions between them. From the main panel, the operator can monitor the status of all subsystems, instantly find the source of possible problems, issue commands to the LV, HV and ECAL VME Crates Control subsystems and manually shutdown the whole detector or parts of it in case of any problem.

All commands are sent to the subsystems via a Finite State Machine (FSM) and the states are propagated from the lowest nodes towards the top node. The ON and OFF commands always pass through the STANDBY state, avoiding in this way the HV to be ON when the LV is OFF, which was considered the best solution for preventing problems on the detector's internal devices.

The state transitions and the unexpected states are summarized by the state PARTLY_ON. The FSM state diagram of the detector's partitions is presented on Fig. 2.
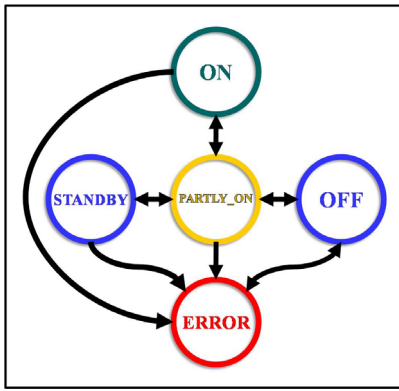
Control System Evolution

Figure 2: ECAL DCS Supervisor's FSM state diagram.

The Supervisor application also handles the automatic controlled shutdown on the detector's partitions level, with granularity of SM/DEE. This mechanism follows a very simple logic (Fig. 3), where changes to error states on applications which monitor the detector's conditions such as air temperature, water temperature and humidity, trigger the shutdown of the concerned partition following the OFF sequence described above.
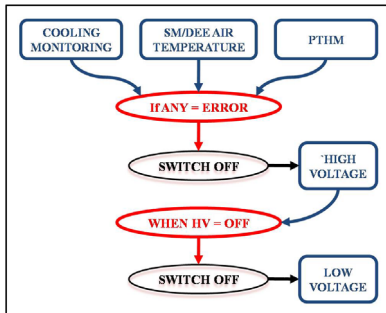

Figure 3: Automatic controlled shutdown sequence.

The Low Voltage

The control and monitoring of all the 860 WIENER MARATON low voltage channels and respective Trigger Tower (TT) inhibits are handled by this application [1,3].

The full application runs on three separate computers due to the limitation on the number of CAN branches per KVASER adapter and to reduce the load per CPU, as the WIENER OPC server is rather resource intensive.

During the detector's running period it became clear that a mechanism to cross check the desired inhibits pattern against the configuration loaded in the crates was absolutely necessary. It was implemented and has proven to work perfectly.

The High Voltage

The control and monitoring of all the 1240 CAEN high voltage channels are handled by this application [1,3], which runs on four separate computers in order to reduce the load per CPU.

In the initial design, the HV settings, stored in the configuration database, could only be applied when all the channels were off. In order to prepare the detector for a non-stop running period, it was decided to enable the command in all states apart from error. This modification

is not yet applied to the production system and will be included in the next releases of the HV application.

The Safety System

A powerful and robust fully redundant PLC system is at the heart of the ECAL Safety System [1-3]. Figure 4 presents a simplified schematic of its inputs and outputs.
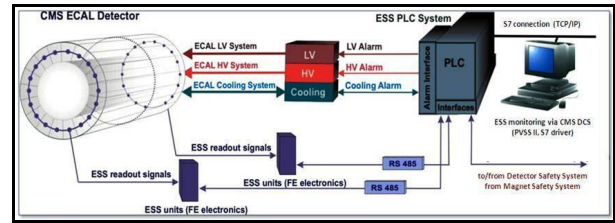

Figure 4: ECAL Safety System layout (simplified).

The initial software design had the ESS integrated as a single application under the ECAL DCS Supervisor. The experience acquired during the operations showed the need for separating the part of the application that is used for the control system from the part that represents the safety system itself. As a consequence, the "SM/DEE Air Temperatures" subsystem was created, based only on the ESS sensors information. Its error conditions are used as a trigger for the DCS automatic controlled shutdown of the concerned partitions.

The Precision Temperature and Humidity Monitoring

The subsystem PTHM [1-3] takes care of monitoring the temperature of the region close to the crystals, by monitoring the cooling temperature of the grid (SM), back plate (DEE) and the respective environmental screens, as well as the SM input and output water temperatures. In addition, it handles inputs from 56 ES temperature sensors, processes the data locally and publishes it as a single element via Data Interchange Protocol (DIP).

The structure of the software application was changed several times during the detector's running period until the optimal solution for the control system was achieved. The final FSM states are "OK' and "ERROR", where the last one is used to trigger automatic controlled shutdowns on the supervisor's level.

The Detector Control Unit Monitoring

The initial project had the DCU application [3] included in the trigger for the DCS automatic controlled shutdown. As the DCU data has proven not to be suitable for such a mechanism, it was re-designed to provide only panels containing the DCU data for information.

The Cooling Monitoring

This application [3] doesn't control the ECAL SM/DEE cooling system, but only monitors the relevant data provided by the cooling PLC, via the Cooling Control. By having tighter temperature limits compared to the ones set in the cooling PLC (which triggers hardwired interlocks to the LV and HV via the ESS), the Cooling Monitoring application is able to trigger the automatic controlled

shutdown of a specific partition before the safety system takes any action based on the cooling water temperature.

The Laser Monitoring

Motivated by the need of the Laser Control system to shut off the laser lamps in situations of unstable magnetic field and the impossibility of this system to directly connect to the CMS DCS to read the desired magnet information, the DCS Laser monitoring application was developed and integrated under the DCS Supervisor.

The CMS DCS publishes all the magnet data to a DIP server, which is then re-published by the ECAL DCS to a Distribution Information Management (DIM) server, from where the Laser Control application reads the data. The laser racks temperatures available on the CMS DCS Racks Control application are also published via DIM. The ECAL DCS Laser Monitoring main panel displays all the laser information which is available on the DIM server, as well as all the information which is re-published from the CMS DCS.

The ECAL Preshower Control and Monitoring

The ES DCS application is not discussed in details in this paper. Its software layer is fully integrated under the ECAL DCS Supervisor, from where the sub-detector can be controlled. Figure 5 presents the ES simplified layout.
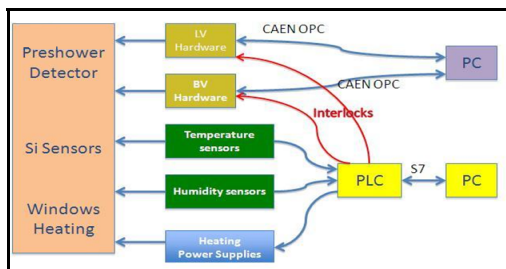

Figure 5: The ECAL Preshower layout (simplified).

The ECAL VME Crates Control

This service is provided by the CMS DCS and was integrated under the ECAL DCS Supervisor to serve as an auxiliary tool to control remotely the power to the ECAL EB/EE VME crates.

THE ECAL OPERATIONAL EXPERIENCE

The period of commissioning and cosmic running was efficiently used to test the DCS hardware in the CMS environment, as well as all its interfaces to other systems. A permanent ECAL DCS expert on-call service was provided during the whole detector's running period.

On a single occasion, due to an operational mistake while the ECAL EB/EE were fully powered, the safety system could not react and set the proper interlocks during a cooling system failure, resulting in a mild overheating of the detector. The prompt DCS expert's intervention prevented the detector from reaching temperatures which could cause damages to its electronics. This optimal reaction time was guaranteed by the cooling control alerts system, which instantly issues emails and SMS whenever a problem is detected. After the incident, a complete set of reviews of the ECAL Safety and Control Systems was carried out in order to identify all possible issues which could lead to similar events. All alerts systems were improved in order to always guarantee the optimal response time in case of problems.

All shutdowns, on the hardware level, triggered by the CMS Safety System (DSS) and by the Magnet Safety System (MSS) were always correctly performed by the ESS.

The automatic controlled shutdown mechanism has proven to be very efficient. The most common trigger for such shutdowns were the CMS primary cooling failures, where the ECAL DCS smoothly switched off the voltages with a reasonable time before the safety system actions.

The ECAL DCS software components were constantly upgraded in order to fulfil all relevant user's requests and consequently to move towards an optimal system. Following the same philosophy, also new applications and mechanisms were added to the initial system's configuration.

CONCLUSION

The acquired experience during the period of commissioning and cosmic running was used for advancing the control system and for better adapting it to the user's needs.

The CMS ECAL DCS has reached a fully operational and stable configuration with further room for both hardware and software improvements. From the operational point of view the system can be considered ready for the LHC startup, which is foreseen for November 2009.

ACKNOWLEDGEMENTS

REFERENCES

[1] CMS collaboration, S. Chatrchyan et al. 2008 "The CMS experiment at the CERN LHC", JINST 3 S08004.

[2] P. Adzic et al., "The Detector Control System for the Electromagnetic Calorimeter of the CMS Experiment at LHC", International Conference on Accelerator and Large Experimental Physics Control Systems, Knoxville, Tennessee, USA, 15 – 19 Oct 2007, pp.190-192.

[3] P. Adzic et al., "Detector Control System for the Electromagnetic Calorimeter in the CMS Experiment – Summary of the first operational experience", Topical Workshop on Electronics for Particle Physics, Naxos, Greece, 15 – 19 Sep 2008, pp.423-427.