Available on CMS information server

CMS CR -2018/230

The Compact Muon Solenoid Experiment

Conference Report

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

29 September 2018 (v3, 09 October 2018)

CMS ECAL Detector Control System Upgrade Plan for the CERN Large Hadron Collider Long Shutdown II

Raul Jimenez Estupinan for the CMS Collaboration

Abstract

The Electromagnetic Calorimeter (ECAL) is one of the detectors of the Compact Muon Solenoid (CMS) experiment at the CERN Large Hadron Collider (LHC). The ECAL Detector Control System (DCS) software has been implemented using the WinCC Open Architecture (OA) platform. Modifications that require fundamental changes in the architecture are deployed only during the LHC long shutdowns. The upcoming long shutdown (2019-2020) offers a unique opportunity to perform large software updates to achieve a higher modularity, enabling a faster adaptation to changes in the experiment environment. We present the main activities of the ECAL DCS upgrade plan, covering aspects such as the re-organization of the computing infrastructure, the consolidation of integration tools using virtualized environments and the further usage of centralized resources. CMS software toolkits are evaluated from the point of view of the standardization of important parts of the system, such as the machine protection mechanism and graphical user interfaces. Many of the presented features are currently being developed, serving as precursors to the major ECAL upgrade foreseen for the next long shutdown (2024-2025).

Presented at *PCaPAC2018 12th International Workshop on Emerging Technologies and Scientific Facilities Controls*

CMS ECAL DETECTOR CONTROL SYSTEM UPGRADE PLAN FOR THE CERN LARGE HADRON COLLIDER LONG SHUTDOWN II

R. Jiménez Estupiñán, D. Di Calafiori, G. Dissertori, L. Djambazov, W. Lustermann, S. Zelepukin[1],
ETH, Zurich, Switzerland
[1]also at University of Wisconsin-Madison, USA

Abstract

The Electromagnetic Calorimeter (ECAL) is one of the detectors of the Compact Muon Solenoid (CMS) experiment at the CERN Large Hadron Collider (LHC). The ECAL Detector Control System (DCS) software has been implemented using the WinCC Open Architecture (OA) [1] platform. Modifications that require fundamental changes in the architecture are deployed only during the LHC long shutdowns. The upcoming long shutdown (2019-2020) offers a unique opportunity to perform large software updates to achieve a higher modularity, enabling a faster adaptation to changes in the experiment environment. We present the main activities of the ECAL DCS upgrade plan, covering aspects such as the re-organization of the computing infrastructure, the consolidation of integration tools using virtualized environments and the further usage of centralized resources. CMS software toolkits are evaluated from the point of view of the standardization of important parts of the system, such as the machine protection mechanism and graphical user interfaces. Many of the presented features are currently being developed, serving as precursors to the major ECAL upgrade foreseen for the next long shutdown (~2024-2025).

INTRODUCTION

The CMS Electromagnetic Calorimeter (ECAL) detector is composed of a scintillating crystal calorimeter and a lead/silicon preshower. The CMS experiment takes collisions data at the LHC, requiring extremely high reliability and the minimum down-time of the various detectors. The ECAL detector is subdivided in partitions as follows: Barrel (EB), Endcaps (EE) and Preshower (ES). The EB partition consists of 36 Supermodules (SM) each containing 1700 crystals, the EE consists of two endcaps split in four semi-circles (Dees), each containing 3662 crystals, and the ES consists of two circular structures.

The DCS controls and monitors the status of the hardware of each partition: cooling, powering systems, safety systems, environmental monitoring systems and other external interfaces. The DCS software coordinates the interaction between the different subsystems, providing an effective and meaningful way of operating the detector. From the architectural point of view, the DCS software is built by a hierarchy of components, whose main features can be organized into one of the following categories: Systems Configuration (peripheral addresses, database archivers, alarms, notifications, etc.), Finite State Machine (FSM), Automatic Actions (AA) and User Interfaces (UIs).

The CMS ECAL DCS [2] has successfully supported the ECAL operations since the CMS commissioning, more than 10 years ago. The CMS detectors maintenance is mainly driven by the LHC schedule, often restricted to periods of 2 to 5 days, called Technical Stops (TS). Major modifications are postponed to the Extended Year-end Technical Stops (EYETS) or the LHC Long Shutdowns (LS). The next LS will last for about two years, starting at the end of 2018. During this period, also known as the Second Long Shutdown (LS2), multiple activities across the LHC, Injectors and LHC Experiments will be performed [3]. Following the previous re-integration and consolidation of the CMS ECAL DCS [4], the LS2 provides an ideal opportunity to bring new features into operation, improve the maintainability of the CMS ECAL DCS software and increase the level of availability of the systems.

DCS UPGRADE PLAN OVERVIEW

Multiple activities are scheduled for the LS2; however, this paper focuses on those that imply significant changes to the DCS architecture:

- Re-configuration of the low voltage powering system. The device distribution at the Controller Area Network (CAN) level will be modified to increase the overall performance of the system;
- Extension of the protective automatic actions. The plan includes a proposal to increase the granularity of the current actions, the implementation of new ones and the evaluation of existing frameworks;
- Software standardization. The existing development guidelines will be extended and applied during the creation/modification of every component.
- Consolidation of the CMS ECAL DCS test platform. The usage of CMS automated deployment and testing tools will contribute to have faster development cycles, while reducing the time spend on maintenance;
- Improvements in the Programmable Logic Controller (PLC) based protection and safety systems.

Some of the LS2 activities present dependencies that define the order in which they must be executed (e.g. software updates come after the changes in the hardware layout). The LS2 upgrade plan is organized according to the tasks priority and dependencies (See Fig. 1) and it will be refined in the upcoming months, in order to meet all the requirements presented by the ECAL community.

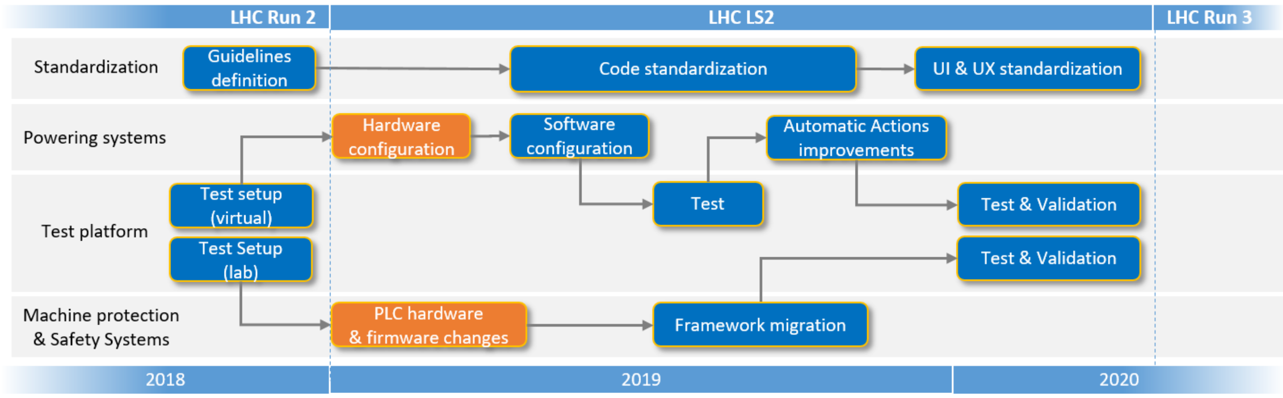

Figure 1: ECAL DCS upgrade plan for the LS2.

RECONFIGURATION OF THE LOW VOLTAGE POWERING SYSTEM

The ECAL powering systems are classified into two categories: Low Voltage (LV) and Bias Voltage (BV) power systems. The LV system for the EB and EE partitions is composed of 136 Wiener [5] Marathon power supplies, distributed across 10 CAN buses. The CAN buses for the LV system are connected to CAN-to-Ethernet interfaces enabling the access over the CMS private Ethernet network. The EB/EE BV and ES LV and BV are based on CAEN [6] power supplies using built-in Ethernet interfaces.

In the past years, the connection between the DCS and the EB/EE LV system has been affected by disruptions in the CMS private Ethernet network. When the communication is disrupted, the driver qualifies the data as invalid, similarly to an internal failure of the power supplies. Upon this condition, the CMS ECAL DCS is programmed to shut down the affected partitions (SMs or Dees) as a preventive action. After a few of such incidents, several tests were performed to understand the data invalidation process with the help of a network disruptor device. The tests focused on the two aspects: the disruption time required by the driver to invalidate the data and the time required to reconnect and restore the communication. Among other things, the tests revealed that the performance of the driver depends on the distribution of devices across the different buses. This means that the most populated bus determines the overall recovery time after such incident. This particular conclusion motivated the following activities for the LS2: extension of the number of buses connected to the CAN bus interface from 10 to 12 buses, redistribution of devices across the buses (maximum 15 devices per bus) and the reorganization of the DCS software according to the new interface layout (See Fig 2.). These changes, together with a new driver's configuration, will help to increase the overall performance of the LV network, making the DCS more tolerant to disruptions. This task requires the assignment of new peripheral addresses, the renaming of multiple structures and a crosswise reconfiguration of the software to ensure the correct integration of the changes.

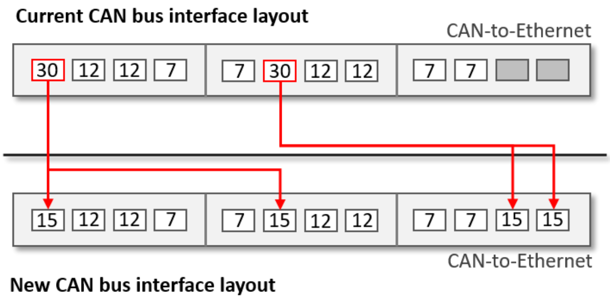

Figure 2: Changes in the CAN-to-Ethernet interface layout. The number of power supplies in each CAN bus is indicated in the white squares.

EXTENSION OF THE PROTECTIVE AUTOMATIC ACTIONS

The automatic actions in the DCS are preventive measures intended to protect the detector before escalating the problem to the safety systems. Actions are programmed to prevent delivering power during harmful conditions (e.g. absence of cooling, high humidity, etc.). The current implementation will be analysed and possibly extended to include the following features:

- Creation of new triggering conditions based on temperature information of the power supplies.
- Finer granularity of the automatic actions for the EE and EB partitions.
- Standardization of the protective automatic actions.

Finer granularity of the automatic actions

Currently, the automatic actions for the EB and EE partitions are executed with the granularity of one SM or Dee. Each SM is powered by 3 LV Marathon power supplies and 34 BV channels. Dees are powered by 7 LV Marathon power supplies and 12 BV channels. This means that a single channel failure in a LV power supply triggers an action over a large number of devices regardless of their status, compromising the CMS data quality. A concrete proposal to increase the granularity of the automatic actions will be presented in the upcoming months, following a thorough analysis to prove the feasibility of this modification.

Standardization of the protective automatic actions

The protective automatic actions in the CMS ECAL DCS are programmed following different approaches [7]. The ECAL Finite State Machine (FSM) embeds most of the automatic actions for the EB and EE partitions, while the rest of the actions are implemented in custom control scripts. Other mechanisms to program automatic actions are also available to the CMS community. The Detector Protection is a software framework using the WinCC OA distribution capabilities and its native locking mechanism for exclusive data access. This framework offers a single interface to configure and monitor actions across distributed systems in a uniformed way. This framework is currently used by multiple projects within CMS and its usage will be considered after evaluating aspects such as the scalability of the software.

CONSOLIDATION OF THE TEST PLATFORM

The current CMS ECAL DCS computing infrastructure is composed of three redundant servers. Each server features 16 CPU cores, 32 gigabytes of RAM and runs the Windows 2008 Enterprise R2 operating system. The DCS software components are distributed among these servers according to their functionality and the hardware connected to them. The computing load and distribution of concerns is considered optimal, resulting in a highly cohesive system with very low coupling between the different software components. The configuration of the control platform (distributed and redundant connections, network parametrization and components layout) is stored in a central installation database.

Since the beginning of 2018, the CMS ECAL DCS team uses a set of CMS installation tools to perform unattended software deployment in the test setups. These tools are able to access the DCS installation databases and build the latest version of the software using the official code repositories. In addition to this, the installation tools are able to monitor changes and to synchronize the development copies with the production systems. The computing hardware used for the test setup is similar to the one used in production (except for the redundant set of nodes) and it will be extensively used during the LS2 for performance analysis, debugging and automated testing.

Virtual test environment

In addition to the physical test setup, three virtual machines from the CMS computing infrastructure are also available for testing. Each of them provides with 4 virtual CPUs, 8 GB of RAM and 40 GB of disk storage, sufficient to run an offline copy of the CMS ECAL DCS software. This virtual setup is particularly useful for developing multiple features in parallel, while minimizing the time required for maintaining the infrastructure. The usage of virtual machines permits the reinstallation of the operating system within minutes, having a ready-to-use copy of the CMS ECAL DCS software within a few hours. The virtual environment will be used during the LS2 to fragment and speed up the different software developments (See Fig 3.).

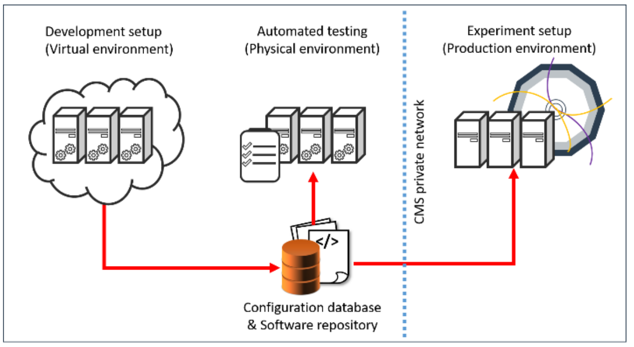

Figure 3: Software deployment process.

SOFTWARE STANDARDIZATION

The CMS ECAL DCS software was written by multiple developers, using different design criteria and programming styles. During the latest re-integration, the software was reorganized following a set of recommendations for controls systems development, in compliance with the existing JCOP framework [8] and CMS Central DCS integration guidelines [9]. Part of this reorganization work focussed on merging applications, migrating the DCS to the latest generations of software/hardware technologies, while adapting the architecture to run in fewer but more powerful servers. The resulting architecture was successfully adjusted and simplified, enabling the reduction from fifteen to three servers. Many software components execute similar tasks over different domains and areas of the detector (e.g. configuring and monitoring hardware, triggering protective automatic actions, etc.). However, the different implementations may differ substantially from each other, making the overall architecture sometimes difficult to evolve or maintain. One of the goals for the LS2 is to extend the existing guidelines, homogenize and incorporate new functionality by means of common libraries. The new guidelines will put the focus on specific naming conventions and programming best practices to improve the ECAL DCS software in the following areas:

- Code styling: Uniform naming and declaration rules for functions and variables will be introduced incrementally to improve the clarity, maintainability, extendibility of the code;
- Shared functionality: Similar tasks across components will be abstracted and encapsulated (e.g., resolution of hardware dependencies, storage of mappings, etc.)
- Debugging and diagnostics tools: New functionality will be introduced to extract run-time information from the systems and to improve the application message logging;
- User interfaces: Some of the user interfaces will be redesigned to improve information handling and to ease the support service during the on-call operations.

MACHINE PROTECTION AND SAFETY SYSTEMS

The CMS ECAL detector features Siemens PLC [10] based safety systems, in addition to the CMS Safety System (DSS). The environmental conditions inside the EB and EE partitions are monitored through custom read-out units, transmitting the sensors data to the PLC through RS485 buses. The environmental conditions inside the ES partitions are directly monitored by two other controllers, whose core functionality is implemented using the CMS Tracker PLC framework. The Tracker PLC framework is a compilation of tools to develop PLC applications for particle detectors. The framework permits a certain level of parametrization (alarm limits, deactivation of broken sensors, etc.) from the DCS supervisory layer. At the moment, these features are present in the two ES PLCs and some of them will be activated and integrated into the DCS interface. Further steps in the migration to this framework are also foreseen for the EB and EE Safety PLC, aiming to provide a higher level of support using the CMS ECAL DCS user interfaces.

CONCLUSION

Starting from a well consolidated software, the CMS ECAL DCS team seeks now for an efficient, extensible and more maintainable architecture. The adoption of common frameworks, development guidelines and tools will help to reduce the maintenance efforts while improving the support of critical parts of the system. In addition to this, the changes in the CAN bus interface and the protective automatic actions will contribute to increase the overall performance of the detector by providing a more reliable and robust system for the next physics operations in 2020.

ACKNOWLEDGEMENTS

The authors would like to thank the Swiss National Science Foundation for the financial support, as well as the CMS Central DCS team and the CMS Tracker DCS team for sharing some of the tools mentioned in this paper.

REFERENCES

[1] SIMATIC WinCC OA [online], http://www.etm.at/index_e.asp

[2] D. Di Calafiori et al., "The CMS ECAL Detector Control System", ICALEPCS'2009, Kobe, Japan (2009)

[3] M. Bernardini et al., Long Shutdown 2 @ LHC, CERN, Geneva, Switzerland.

[4] O. Holme et al., Re-integration and Consolidation of the Detector Control System for the Compact Muon Solenoid Electromagnetic Calorimeter.

[5] Wiener Electronics for Research & Industry [online], http://www.wiener-d.com/

[6] CAEN Tools for discovery [online], http://www.caen.it/

[7] R. Jimenez Estupinan et al., Improving the safety and protective automatic actions of the CMS Electromagnetic Calorimeter Detector Control System.

[8] "Joint Controls Project (JCOP) Framework sub-project guide-lines and conventions", JCOP Framework team, 20th October 2010.

[9] R. Gomez-Reino, CMS DCS Integration Guidelines, 2007, [online], https://twiki.cern.ch/twiki/bin/view/CMS/DCSIntegrationGuidelines

[10] Siemens PLC, [online], https://www.siemens.com/global/en/home/products/automation/systems/industrial/plc.html