THE COMPACT MUON SOLENOID DETECTOR CONTROL SYSTEM

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Abstract

The Compact Muon Solenoid (CMS) experiment at CERN is one of the Large Hadron Collider multi-purpose experiments. Its large subsystems size sum up to around a million Detector Control System (DCS) parameters to be supervised. A cluster of ~100 servers is needed to provide the required processing resources. To cope with such a size a scalable approach has been chosen factorizing the DCS system as much as possible. CMS DCS has made a clear division between its computing resources and functionality by creating a computing framework allowing for plugging in functional components. DCS components are developed by the subsystems expert groups while the computing infrastructure is developed centrally. To ease the component development task, a framework based on PVSSII has been developed by the CERN Joint Controls Project (JCOP). This paper describes the current status of CMS Detector Control System, giving an overview of the DCS computing infrastructure, the integration of DCS subsystem functional components and the experience gathered so far.

INTRODUCTION

Following an exhaustive engineering study, CERN Council has decided that collisions at the Large Hadron Collider (LHC) will start before the end of current 2009 year. After a decade of preparation, CMS control system is ready to guarantee accurate and uninterrupted operation so that its detector data acquisition system can take high quality physics data. LHC experiments have largely overcome earlier ones in many aspects, including the amount of sub-systems and their complexity. The number of channels that CMS control system has to deal with couldn't be handled only relaying on today's much greater computer processing power, but there is also a need of means to maintain a complex computing hardware and software infrastructure. A control system capable to deal with an experiment such as CMS should allow for hardware replacement, minimizing (when not eliminating) the impact on the detector operation. Together with this hardware maintenance flexibility, the software infrastructure should allow for extensions, upgrades or modifications in a modular, and controlled error-free fashion. LHC experiments have not only changed technically but also in terms of man power. CMS collaboration involves 183 institutes in 38 countries. Sub-detector control systems laid under different institutes' responsibilities and the range of ~100 scientists have worked on its development at different stages. Whit this important number of people involved, the risk of ending up with a quite heterogeneous and uneven system also has to be confronted. A homogenous system is mandatory to reduce the manpower cost for maintenance and operation during the long years in which CMS would be in operation.

DESIGN APPROACH

A complete separation between computing resources and control system functionality is a unique characteristic of CMS control system at LHC.

Computing Resources

The control system computing resources management in CMS extends the classical computer administration functions. It includes the following items:

- Operating system deployment
- Software installation (hardware drivers and applications)
- Databases access configuration
- SCADA base configuration and control system functionality installation
- Remote web-based server management tools

For the DCS software deployment CMS uses CERN Computer Management Framework (CMF). This management tool allows defining sets of computers that can be selected to install software packages and policies. Computers may belong to many sets, inheriting the software packages of each of them. A substantial pool of CMF software packages for most commonly applications used at CERN has been developed by central IT groups. However, CMS also created its own CMF packages for custom drivers and control software installation.

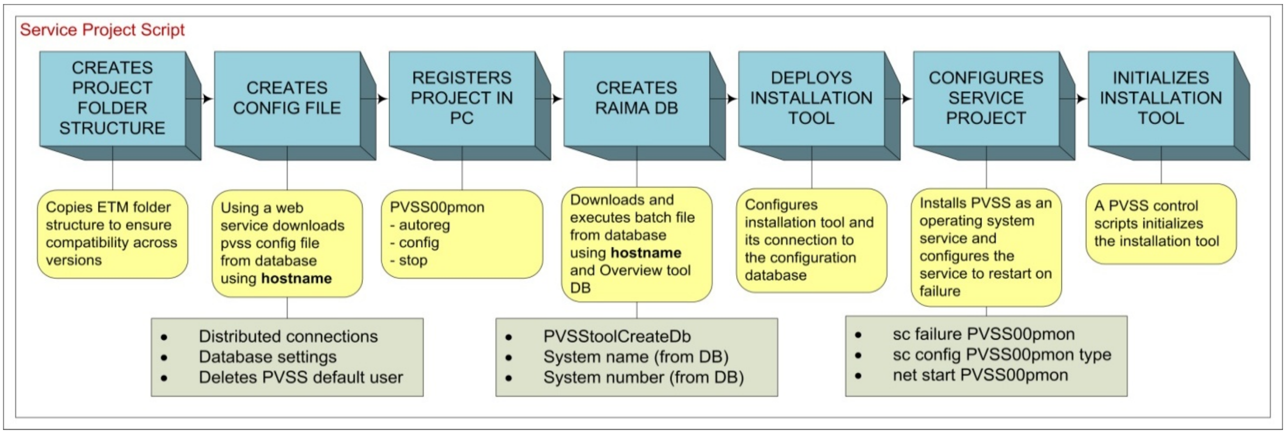

Figure 1: CMF package details for PVSS project creation.

A CMF package was created to connect control system servers to the experiment configuration and conditions database. Another CMF package, Fig. 1, was developed to create PVSS SCADA projects in control system servers. PVSS projects are created in each control server with independent settings described in a configuration database. Identifying control system names and numbers and the distributed connection between them are configured at creation time. PVSS in installed as an operating system service, starting automatically after an eventual server reboot. At last, this CMF package triggers CERN Joint Controls Framework (JCOP) distributed installation tool, which was developed in collaboration with CMS. This installation tool takes care of the deployment of the production versions of JCOP framework components as well as the installation of CMS functional components.

Control System Functionality

Following central DCS development guidelines [1], sub-detector developers create functional components in separated development environments. Functional components contain all information needed to address hardware, configure alerts, set archive smoothing settings, declare access control privileges and define the high level behavioural logical rules of a detector control sub-system. Using JCOP distributed installation tool and its versioning mechanism production CMS detector functional components can be upgraded or rolled back to newer or older versions. Table 1 summarizes the existing number of sub-system functional components in CMS production and the hardware that they are controlling. Functional components have been created by sub-detectors to control high and low voltage power supplies and to monitor detector environment parameters such as temperature and humidity of their electronics. A central DCS team has also developed functional components for central services such as cooling, magnet monitoring, electronic racks power control or VME crate control. Functional components are usually generic, this meaning that a high voltage supply component from the tracker system is installed in many tracker servers but controlling different hardware. Functional components use the information on a configuration database to find out the hardware they should address. Functional components are however not installable across sub-detectors without substantial modifications.

Table 1: CMS Detector Functional Components

System Name	Number of Components	Number of Servers	Monitored Parameters
Tracker	10	14	350k
Calorimeter	27	14	115k
Muon	30	30	435k
Trigger	2	2	1k
Alignment	4	3	3k
Services	25	35	20k

Remote Management Tools

A set of web applications has been developed by central DCS so that sub-detector control experts can manage their control system servers and monitor their computing resources without directly accessing their rack mounted servers. The applications are based on Oracle Portal technology. Oracle Portal is a browser based, self-service, content publishing and development solution that allows end users and web developers to build data driven web sites. CMS Portal is fully integrated with the experiment databases and WebPages were created to display archived conditions and detector configuration information. Not only archived data is presented via CMS Portal pages but also live information about SCADA processes, server status and distributed active connections across systems can be monitored. An Oracle integrated access control management system allows also giving privileges to users so that they don't only monitor but can also start and stop control processes.

Functional Component Management

Sub-detectors experts can deploy new versions of their functional component using a web Portal application. This application sends the requests directly to the JCOP installation tool configuration database. The installation tool performs regular consistency checks between PVSS projects configuration and their database defined configuration, and processes any pending request such as a new component version installation, deletion or upgrade.

DETECTOR CONTROL SYSTEM STATUS

System Functionality

CMS has developed and put into production about 100 functional components covering approximately a million parameters monitored and several tens of thousands of power supply channels controlled. The development of these components was done following CMS DCS Guidelines provided by a central DCS team. With these guidelines, CMS has achieved a considerable degree of homogeneity across the distributed control system. It is expected that this homogeneity reduces considerably the learning curve of new manpower resources and also simplifies the future system maintenance.

System Maintainability

The separation of the computing resources and the control system functionality allowed for a precise division between development and production environments. CMS control system experts need not to (and cannot) modify the computing resources environment and this way they can rather put their attention into control functionality improvements. The automation of the computing resources management allows CMS to easily replace broken servers without the intervention of control system experts. Like this, CMS accomplish also the mission of creating a long term maintainable system where new nodes can be easily installed, broken ones can be recovered and existing ones can be reconfigured using global applications.

System Operation

To conclude the distributed system integration, central DCS team has created a top control layer consisting on a hierarchy of logical nodes modelling the behaviour of the control system related with each detector data acquisition trigger partition. Logical nodes behaviour are modelled using SMI++ [2] adaptation for PVSS, the JCOP Finite State Machine (FSM) toolkit [3]. This top FSM layer allows operators to control CMS sub-detectors without distinction, using similar commands that are later eventually interpreted differently by each sub-detector partition. This layer is also used to communicate with the experiment Run Control and handles the handshake with the LHC machine.

EXPERIENCE GATHERED AND PLANS

CMS bet on a design concept for its control system with a considerable initial cost on time, both because of the management infrastructure development and because of the control system experts' adaptation to the environment under construction. However, the initial cost has already been compensated and complete distributed system upgrades have been performed in time slots where it would have not been possible to fit without the chosen design.

DCS Unification

The homogeneity degree achieved with CMS DCS Development Guidelines has been satisfactory and as a result of this CMS has been able to export solutions across sub-systems. However, with the expertise gathered, CMS wants to go one step further in the homogeneity direction and achieve real control system unification. The DCS Unification task force has the mandate to redesign (in 1.5 year), the functional components of CMS so that they are as more generic as possible. The experience gathered shows that in order to confront this task a reorganization of the manpower is needed. Fig. 2 presents the simple reorganization concept.

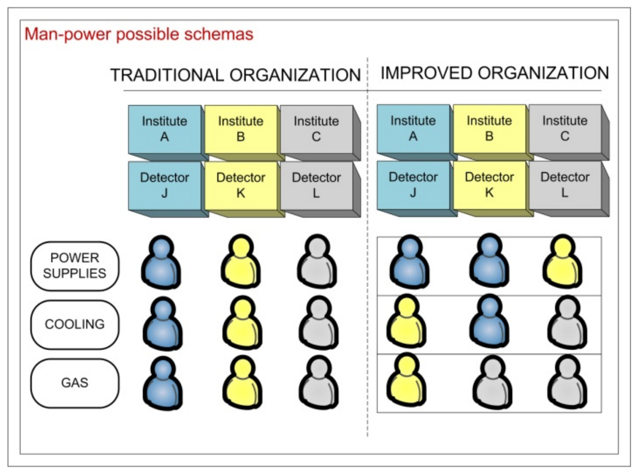

Figure 2: Man-power reorganization.

Traditionally, institutes would take responsibility of sub-detectors or sub-systems developing all functionality independently. The named *improved organization* uses a pool of developers that work together in common functional components used by all sub-detectors. This way homogeneity should be achieved across applications and across sub-systems. While its control system is ready and fully operational CMS is working in a redesign that will perhaps convert its control system in a referent for future large experiments.

REFERENCES

[1] R. Gomez-Reino et al, "CMS DCS Design Concepts", ICALEPCS 2005

[2] B.Frank, C.Gaspar, "SMI++ Object Oriented Framework for Designing and Implementing Distributed Control Systems", SLAC-PUB-12067 http://www.slac.stanford.edu/pubs/slacpubs/12000/slac-pub-12067.html

[3] A Finite State Machine Toolkit, http://lhcb-online.web.cern.ch/lhcb-online/ecs/fw/FwFsm.html