Maintaining an effective and efficient control system for the Electromagnetic Calorimeter of the Compact Muon Solenoid experiment during long-term operations of CERN’s Large Hadron Collider

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For the CMS collaboration
Overview

1. CMS Electromagnetic Calorimeter (ECAL)
2. Detector control system (DCS) architecture
3. Challenges
4. Approaches
5. Conclusions
Barrel & Endcaps
Lead tungstate (PbWO₄) scintillating crystals
Photodiodes / phototriodes detect generated light

Preshower
Silicon strip sensors
## Essential CMS ECAL DCS requirements

### Monitoring

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Probes/Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>972 probes</td>
</tr>
<tr>
<td>Humidity</td>
<td>180 probes</td>
</tr>
<tr>
<td>Cooling system monitoring</td>
<td>3 independent systems</td>
</tr>
</tbody>
</table>

### Control

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Channels/Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low voltage</td>
<td>1’060 channels Wiener &amp; CAEN</td>
</tr>
<tr>
<td>Bias voltage</td>
<td>1’624 channels CAEN</td>
</tr>
</tbody>
</table>

### Detector protection

- Software level protection actions
- Siemens PLC safety systems for interlocks
Current Architecture

15 DELL rack servers

- USB
- CAN

SYS-TEC electronic USB-CAN converters

WIENER power supplies

Embedded Local Monitor Boards (ELMB)

2 collaborative design from CERN, NIKHEF and PNPI

Other software applications

- Siemens PLCs
- CAEN power supplies

- Windows XP
- WinCC OA 3.8 SP2 (formerly PVSS)
- JCOP Framework
- Hardware drivers

1 collaborative project from CERN and LHC experiments
Challenges for the CMS ECAL DCS

High software maintenance
• Diverse component design
• Reduced staff numbers
• Consolidation required

Technological developments
• Release & support cycles
• Interdependencies
• Benefits of new technology

Extension of requirements
• Resulting from operational experience
• Need to avoid growing complexity
• Limit number of technologies
Software Consolidation

Software Analysis Project
- Factor out common functionality
- Homogenization
- Remove unneeded features

ECAL DCS Software
Analysis Outcomes
Improved Software
Continuous Quality Assessment

New Requirements
Before (January 2011)

- Lines of code: 67’532
- Duplicated code marked in **RED**

After (October 2011)

- Lines of code: 59’655
- Code reduced by more than 10%
Continuous Quality Control Impact

Without (October 2011)

- Lines of code: 59’655
- Duplication after analysis project

With (October 2012)

- Lines of code: 37’124
- Code reduced by another 35%
Handling new requirements

- **New requirements**
  - **Existing knowledge**
  - **Supported technologies**
  - **Expert Analysis**
  - **Optimal design**

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**Preshower bias voltage monitoring**
- Based on existing ELMB design and experience

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**Improved humidity monitoring**
- Custom electronics essential for existing probes
- Modbus chosen for readout due to WinCC OA support

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Adopting new technologies

Smooth migration is essential
  – Restrictive upgrade schedule

CMS ECAL DCS replica lab setup
  – Research, development and validation
  – Fewer problems seen during deployment

Upcoming migrations (2013-2014)

<table>
<thead>
<tr>
<th>New DELL blade servers</th>
<th>✔ Validated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows 7</td>
<td>✔ Validated</td>
</tr>
<tr>
<td>CAN readout via Ethernet</td>
<td>In progress</td>
</tr>
<tr>
<td>WinCC OA 3.11</td>
<td>Pending</td>
</tr>
<tr>
<td>JCOP Framework 5.0</td>
<td>Pending</td>
</tr>
</tbody>
</table>
Conclusions

• Approaches have yielded benefits:

1. Consolidation and quality monitoring
   • Code size reduced by 45%
   • More consistency between components

2. Reusing existing technologies
   • Rapid development of DCS extensions
   • Complexity of system is controlled

3. New technology research and development
   • Smooth migration to new technologies
   • Benefit obtained from new features

Robustness maintained with extended functionality