Improving the Compact Muon Solenoid Electromagnetic Calorimeter Control and Safety Systems for the Large Hadron Collider Run 2

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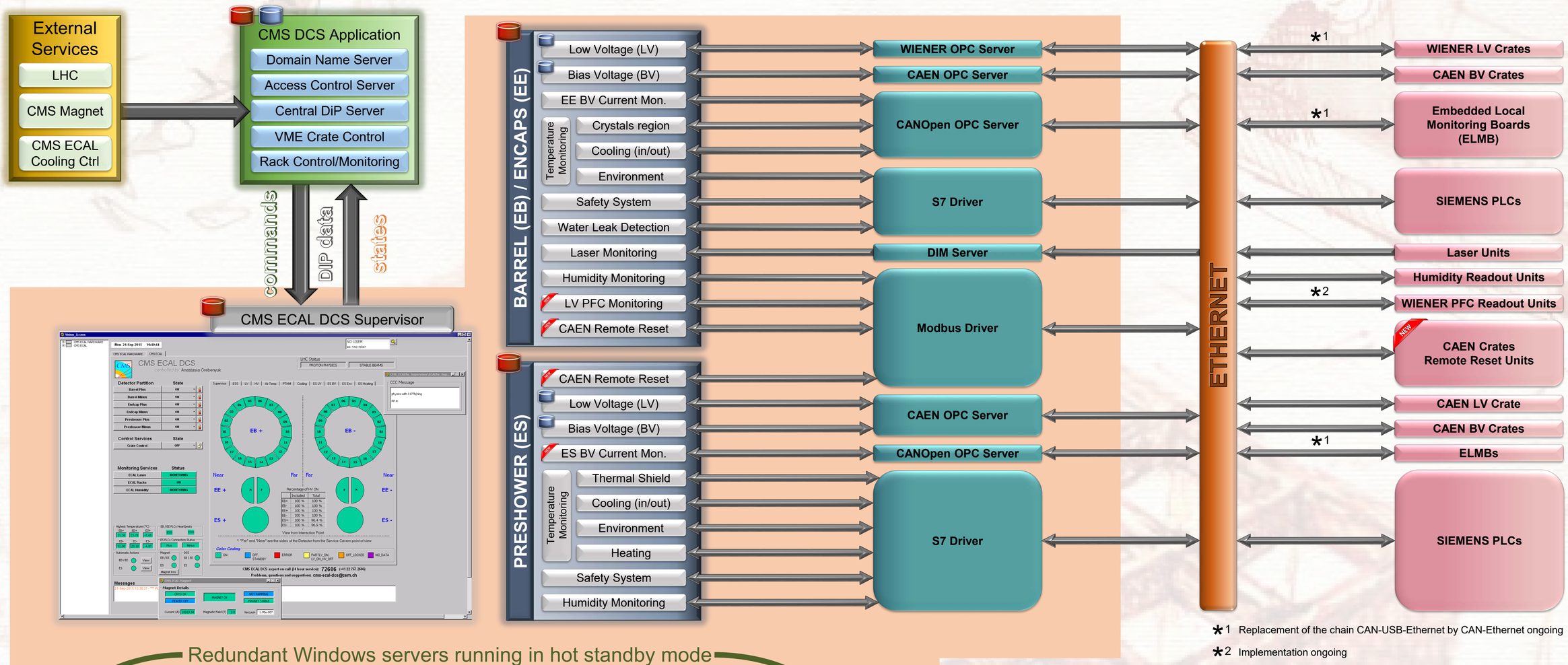
On behalf of the CMS Collaboration

The CMS ECAL Detector Control System



*1 Replacement of the chain CAN-USB-Ethernet by CAN-Ethernet ongoing

*2 Implementation ongoing

Redundant Windows servers running in hot standby mode

3 servers
@ CMS service cavern

- Based on the WinCC Open Architecture software package
- Uses Joint COntrols Project (JCOP) and CMS frameworks
- 3-role access control (MONITOR / OPERATOR / EXPERT)
- Applications archive / retrieve data from central databases
- Alerts and protective automatic actions at all system levels

3 servers
@ CMS data center

24/7 On-call Services

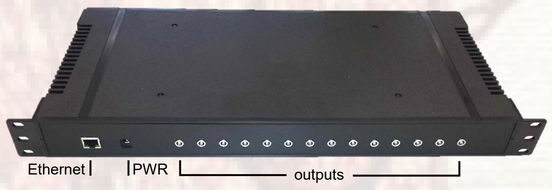
- Two levels: Operator / Expert (also responsible for the safety system hardware)
- Contributes to the maximum availability of the detector
- Log of failures used for further system improvements and corrections

DCS software | Software interface | Use of Configuration DB
Off-detector hardware | Hardware interface | Use of Conditions DB

Remote reset of CAEN mainframes

CAEN mainframe overview

DCS Name	Network Name	IP Address	Location	ECAL Partition	Clear Alarms	CPU Reset	Full Reset
ES_HV	ESHV01	10.176.62.22	S2G05	ES+ HV	Clear Alarms	CPU Reset	Full Reset
ES_HV2	ESHV02	10.176.62.24	S2G05	ES- HV	Clear Alarms	CPU Reset	Full Reset
ES_LV	ESBV01	10.176.64.13	S4F03	ES+ LV, ES- LV	Clear Alarms	CPU Reset	Full Reset
cmsechv01	ECALHV11	10.176.3.10	S2B06	EB+1, EB+2	Clear Alarms	CPU Reset	Full Reset
cmsechv02	ECALHV12	10.176.62.109	S2B06	EB+3, EB+4	Clear Alarms	CPU Reset	Full Reset
cmsechv03	ECALHV13	10.176.62.111	S2B06	EB+5, EB+6	Clear Alarms	CPU Reset	Full Reset
cmsechv04	ECALHV14	10.176.3.62	S2B07	EB+7, EB+8	Clear Alarms	CPU Reset	Full Reset
cmsechv05	ECALHV15	10.176.62.107	S2B07	EB+9, EB+10	Clear Alarms	CPU Reset	Full Reset
cmsechv06	ECALHV16	10.176.62.108	S2B07	EB+11, EB+12	Clear Alarms	CPU Reset	Full Reset
cmsechv07	ECALHV17	10.176.3.61	S2B08	EB+13, EB+14	Clear Alarms	CPU Reset	Full Reset
cmsechv08	ECALHV18	10.176.62.106	S2B08	EB+15, EB+16	Clear Alarms	CPU Reset	Full Reset
cmsechv09	ECALHV19	10.176.62.105	S2B08	EB+17, EB+18	Clear Alarms	CPU Reset	Full Reset
cmsechv10	ECALHV01	10.176.3.90	S2G06	EB-1, EB-2	Clear Alarms	CPU Reset	Full Reset
cmsechv11	ECALHV02	10.176.62.116	S2G06	EB-3, EB-4	Clear Alarms	CPU Reset	Full Reset
cmsechv12	ECALHV03	10.176.62.115	S2G06	EB-5, EB-6	Clear Alarms	CPU Reset	Full Reset
cmsechv13	ECALHV04	10.176.3.78	S2G07	EB-7, EB-8	Clear Alarms	CPU Reset	Full Reset
cmsechv14	ECALHV05	10.176.62.114	S2G07	EB-9, EB-10	Clear Alarms	CPU Reset	Full Reset
cmsechv15	ECALHV06	10.176.62.113	S2G07	EB-11, EB-12	Clear Alarms	CPU Reset	Full Reset
cmsechv16	ECALHV07	10.176.3.88	S2G08	EB-13, EB-14	Clear Alarms	CPU Reset	Full Reset
cmsechv17	ECALHV08	10.176.62.110	S2G08	EB-15, EB-16	Clear Alarms	CPU Reset	Full Reset
cmsechv18	ECALHV09	10.176.62.112	S2G08	EB-17, EB-18	Clear Alarms	CPU Reset	Full Reset
crateEM	EEHV03	10.176.62.28	S2G09	EE-	Clear Alarms	CPU Reset	Full Reset
crateEP	EEHV02	10.176.62.27	S2B09	EE+	Clear Alarms	CPU Reset	Full Reset



100 ms < t < 200 ms
CPU Controller Reset
Channels remain ON

t > 1000 ms
Full Mainframe Reset
Channels switched OFF

- Arduino Ethernet with Modbus-TCP implementation
- 14 ports per unit, providing TTL output signals
- Heartbeat to ensure the unit availability
- Adjustable pulse length for available reset modes

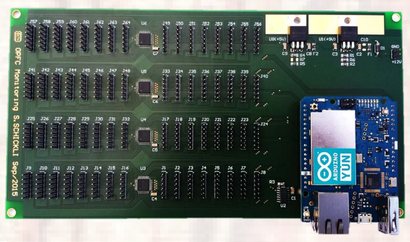
✓ **Easy integration with the detector control system**

✓ **Reduction of intervention time from >30min to <10min**

✓ **Proven effectiveness in production environment**

WIENER PFC monitoring

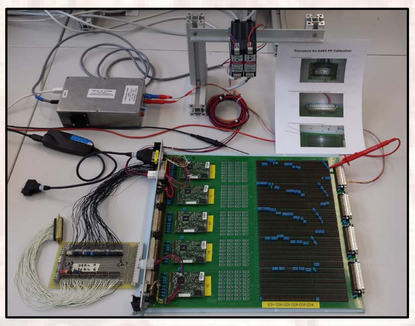
- Readout of internal parameters of 136 Power Factor Correctors (PFC) via RS-232



- Custom electronics features:
  - Arduino Yún with Modbus-TCP implementation
  - 4x dual-channel 16-port MUX for serial line switching
  - 9V and 5V supplies for the PFCs isolated serial circuit

✓ **Easy integration with the detector control system**

ES BV monitoring



- Largest ELMB-based system in the CMS ECAL (80 ELMBs)
- Monitors currents of 2216 individual bias voltage lines
- Readout of currents based on simple resistor networks

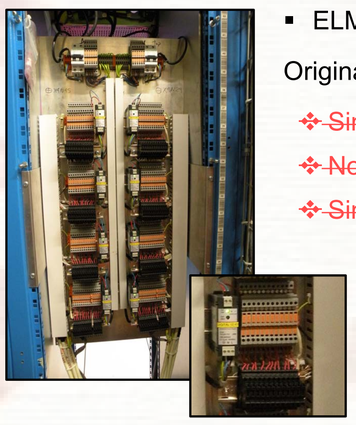
✓ **Readout channels calibrated for precision better than 2%**

✓ **Important for identifying individual increases of currents**

❖ Problem when working in a multiple ground configuration
(investigation ongoing)

Improved PTM ELMB power distribution

- Precision Temperature Monitoring (PTM) of the EB/EE crystals region and cooling



- ELMB-based readout of 516 NTC thermistors

Original ELMB powering scheme:

❖ ~~Single set of 3x 12V power supplies for all ELMBs~~

❖ ~~No easy way to disconnect an individual power line~~

❖ ~~Single failure could degrade the complete system~~

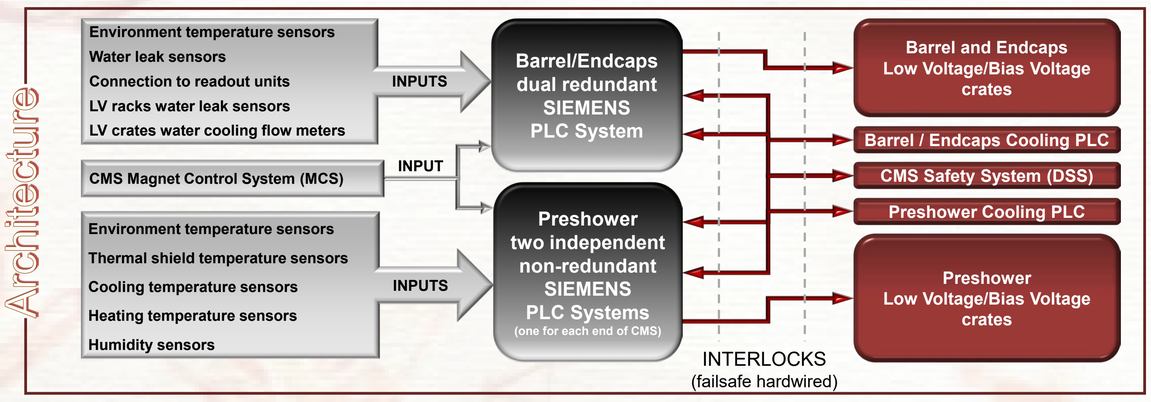
Improved power distribution:

✓ **Two sets of 3x 12V power supplies, one for each detector half**

✓ **Terminal blocks with switches and fuses per power line**

✓ **Failures can be easily isolated at the CMS service cavern level**

Safety system preparation for Run 2

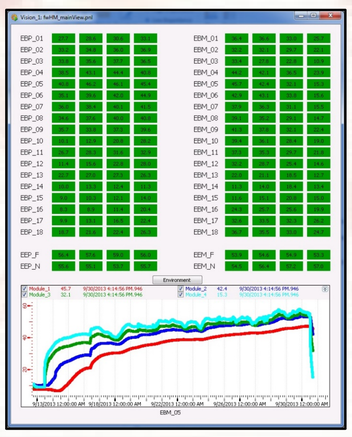


- Preventive maintenance performed regularly
- Protection to prevent users from setting unsafe thresholds
- Annual interlock tests for complete system verification

✓ **CPUs replaced by newer models to ensure support until 2022**

✓ **Software mechanism for recovering communication to readout units**

EB / EE humidity monitoring



- Custom electronics for the readout of 192 RH probes inside EB/EE
- Over one year of evaluation to operate probes out of specifications
- Very low frequency excitation to minimize cabling capacitance effect
- Commercial Modbus RTU-Ethernet adapters used
- Precise calibration at the CMS ECAL DCS laboratory facilities

✓ **Readout range extended from 60-80% to 10-80% RH**

✓ **Expected performance fully demonstrated in production environment**

1) ETH Zurich, Switzerland
2) University of Belgrade, Serbia
3) University of Wisconsin, USA

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