Common Powering Requirements for CMS and Atlas Tracker Upgrades and First Proposals
Outline

• Introduction to the CMS OT requirements
• Introduction to the Atlas OT requirements
• Preliminary specification and common requirements
• First feedback and proposal from the manufacturers
• Next steps
• Conclusion
Introduction to the CMS Outer Tracker powering requirements

The CMS OT powering

- 13296 modules (types: “PS” and “2S”) - individually powered
- Common ground on detector side → RTN line floating at PS end
  - specific isolation requirements (DC and in frequency) b/w HV, LV RTN lines and local ground/earth
- No Vdrop compensation:
  - order of 12V at PS connector, 12-6 V at detector end.
- “Wired” safety:
  - HV OFF when LV OFF in the same module

HV, LV RTN floating at PS end

HV: 0 - 800 V, 3mA
LV: 5-14 V, 1.5 A, 18 W

~ 35 – 80 m ~ 16 Ohm/km
~ 6 m ~ 75 Ohm/km
~ up to 120 cm ~ 280 Ohm/km

12 - 6 V

eff ~ 85%

~ 7.8 W “PS” modules
~ 5.4 W “2S” modules

12 - 6 V

eff ~ 78%

PS module

Opto transceiver

MPPA, SSA
LP-GBT 2.4A
CIC, MPA 1.8A

“PS module”
Macro-pixel & strip sensor

Short Strip ANIC (SSA)

DCCS2
DCDC2S

2.5V
1.25V
1.0V

OptoFEAST

upFEAST

(slides: courtesy of Simone Paoletti, CMS)
Introduction to the CMS Outer Tracker powering requirements

Power grouping

Total of 1224 power cables connecting the OT to power backend
- 12 HV lines per cable
- 12 (or 14) LV pairs per cable (serving detector structures with up to 12 modules)
- LV provided by one regulator and distributed up to 14 LV channels
- HV provided by 12 regulators

(slide: courtesy of Simone Paoletti, CMS)
Introduction to the CMS Outer Tracker powering requirements

Implementation options

LV backend system located on balconies in UXC
- LV cables length < ~50m in order to limit Vdrop
- B ~ 25 mT and 1-10 Gy in 10y HL-LHC

LV and HV systems on same racks in UXC:
- easier implementation of LV/HV interoperation
- sharing interface to interlocks and DCS
48V can be either inside or outside UXC

HV and 48V system in USC
- non-hostile area
- can look to commonality with other sub-detectors
- LV main regulator, LV channels (PSPP), HV channels implemented as separate pieces

(slide: courtesy of Simone Paoletti, CMS)
Introduction to the Atlas Outer Tracker powering requirements

Local on-stave(petal) power distribution

- The basic ITk strip detector unit is a module
- High number of modules, excludes individual powering
  - ITk Strips will have 17888 modules
  - Need to group modules
- Modules grouped in local structures
  - Staves for the barrel. 14 modules per side.
  - Petals for the endcap. 9 modules per side.

- LV and HV have parallel scheme
  - One LV line serves one stave /petal side
  - LV DCDC scheme to reduce currents and power losses on cables
  - Sensor bias multiplexing: HV parallel power on stave/petal => May lose all sensors if one fails as a short. Investigating rad-hard HV switches to be able to disconnect any failed sensors
  - Qualification of HV switches not completed yet => 4 HV lines per side. One HV line for up to 4 modules.
Introduction to the Atlas Outer Tracker powering requirements

Power Requirements

For one stave/petal side:

<table>
<thead>
<tr>
<th></th>
<th>Number of modules</th>
<th>Number of ABC chips</th>
<th>Estimated maximum current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner Barrel LV</td>
<td>14</td>
<td>20</td>
<td>11A</td>
</tr>
<tr>
<td>Inner Barrel HV</td>
<td>14</td>
<td></td>
<td>28mA*</td>
</tr>
<tr>
<td>Outer Barrel LV</td>
<td>14</td>
<td>10</td>
<td>5.5A</td>
</tr>
<tr>
<td>Outer Barrel HV</td>
<td>14</td>
<td></td>
<td>9.3mA*</td>
</tr>
<tr>
<td>Endcap LV</td>
<td>9</td>
<td>8-12</td>
<td>5A</td>
</tr>
<tr>
<td>Endcap HV</td>
<td>9</td>
<td></td>
<td>10mA*</td>
</tr>
</tbody>
</table>

* HV current divided in 4 groups

Maximum current determined for the worst case scenario conditions, namely at the radiation induced current peak of the readout ASICs, and at the end-of-life bias leakage current for the sensors.

Note: These estimates are subject to changes as ASICs and modules will be prototyped and characterized.
Introduction to the Atlas Outer Tracker powering requirements

ITk Strips powering baseline

• In the interests of minimizing the cost, the existing ATLAS Inner Detector (ID) cable plant will be reused as much as possible.
• The current baseline for powering ITk-Strips detector employs:
  – LV DCDC scheme:
    • 48V supplies located in the two service caverns, where radiation and magnetic field levels are negligible.
    • In PP2 areas custom developed step-down DC/DC converters are foreseen to deliver 11V as measured and monitored at the load.
    • The load will be another DC/DC converter at the detector with an operating input voltage of 11V and an absolute maximum of 14 V.
  – HV power supplies will be located in the two service caverns.
  – The power supplies and the power distribution chain are floating with a fixed reference potential established at the detector.
  – The power supplies should be compatible with external detector interlock system
1552 48 V PS channels:
- 272 chan. for Inner Barrel staves, will require 4A output current of the remaining
- 1280 chan. serving Outer Barrel staves and petals, require 2A

3648 HV channels will be required (max. 750 V, 6 mA).
Assuming HV 1-to-2 multiplexing at PP2 for outer barrel staves and petals.
Preliminary common specification

- Common specification drafted in close collaboration with the CMS and Atlas tk teams
- 3 power supply manufacturer’s contacted so far
- Goals:
  - Get power supplies’ experts feedback on the specs
  - Assess feasibility, commonalities, challenges
  - Quantify required development/customisation efforts
  - Improve/mature the tech. specs
  - Identify and decide where/what to investigate/develop
Common requirements

Commonalities

• AC-DC rectifier systems
  – Mains input
  – Output voltage: 48V (optionally higher)
  – Output curr.: 2-6 A (Atlas) and 20-100 A (CMS)
  – Max ripple: 500 mVpp
  – Efficiency: >90%
  – Line and load reg.: 1%

• HV PS
  – AC or DC input
  – Output: 0 to -800 V, 6mA
  – Max ripple: 30 mVpp
  – VI monit. resolution: 12 bits

• Similar monitoring and control features
• Similar interlock and inhibit requirements
• Slow control (OPC UA based)
• All 19” rackable solutions

CMS specific constraints

• Powering of individual detector modules
• Individual wired HV enable according to LV status

Atlas specific constraints

• Re-use of existing cabling
• DC-DC conversion to < 12V will be Atlas home grown
• Individually floating HV channels. Floating range to be defined.
Manufacturer’s proposal (Caen)

**COTS equipment**
- Bulk AC-DC rectifier 48Vdc 4kW
  *Harsh or std environment possible (COTS)*
  *Note: high voltage (e.g. 380V) could be envisaged*
- Modular pwr crate *(std environment)*
- Central control unit *(std environment)*
- Potentially HV modules (depending on location and floating range)

**Required development efforts**
- HV modules with higher current
- LV modules different between both tk, dev. needed *(harsh env. possible)*
Manufacturer’s proposal (Caen)

Proposal

**CMS**

1 HV/LV complex board powers 12 det. modules
- 1224 complex boards
- 204 crates
- 34 branch controllers
- 2 SY4527 (better 4 for redundancy)
- 204 2.5KW-ACDC-PWS (2U COTS)

34 racks in expt cavern + 10 racks in service cavern (bulk AC-DC)

**Atlas**

Modular crate case (partly in expt cavern):
- 456 complex boards
- 77 crates (assuming 6x6 U like the current EASY3000)
- 13 branch controllers
- 77 4KW-ACDC-PWS (2U COTS)
- 1 SY4527 crate

13 racks in expt cavern + 4 racks in service carvern (bulk AC-DC)

All in service cavern case:
- 456 LV boards
- 456 HV boards
- 77 SY4527(1.ctrl+1.service+3.booster)

16 racks in service cavern
Manufacturer’s proposal (Wiener/Iseg)

**COTS equipment**

- Modular “MPOD” HV+LV powering system *(std environment)*
- LV modules: 2ch 48V 4A or 4ch 48V 2A *(std environment)*
- LV modules: 8, 4 or 2ch 0..16V 5A *(std environment)*
- HV modules:
  - 16, 24, 48ch 1kV common float gnd
  - 8 or 16ch 1kV individual float gnd
- Central control module *(std environment)*

**Required development efforts**

- Rad/Mag tolerant DC-DC modules (380V to 4..14V 20A)
- LV distributor module with 12 to 16 output channels (for CMS)
- Possibly higher power density LV modules (+ higher power chassis)
Manufacturer’s proposal (Wiener/Iseg)

Proposal

**CMS**
( Assuming the use of high pwr density modules )

1 LV distribution module + 1 HV mod. powering 2x12 det. modules
- 625 HV + 625 LV modules (24 ch. each)
- 125 MPOD crates
- 125 control modules

11 racks in experimental cavern (LV) + 11 racks (+ bulk AC-DC needs) in service cavern if LV sits in UXC

(Alternatively 22 racks in service cavern)
(Note: Assuming 24ch. HV module is available)

**Atlas**
( Assuming the use of high pwr density modules )

Inner barrel (1LV for 4 HV channels)
- 68 HV (16ch.) + 68 LV (4ch.) modules
- 14 MPOD crates
- 14 control modules

Outer barrel (1LV for 2 HV channels)
- 160 HV (16ch.) + 160 LV (8ch.) modules
- 32 MPOD crates
- 32 control modules

3+6 racks respectively in the service cavern
Next steps

Towards commonalities

- HV power
  - Atlas floating range?
    - <10V
    - No commonality
  - CMS remote HV?
    - Yes
    - No commonality
- LV power
  - No commonality
- AC-DC rectifier
  - 48 or 380 Vdc?
    - 48
- Infrastructure and SW
  - Mainframes, crates, DCS, etc.
  - No commonality

Common, mature and detailed technical specification
Conclusion

• Common specification is possible for some of the powering building blocks
  – AC-DC bulk rectifier, HV power supplies, Control modules and interfaces, interlocking and inhibit features

• Power supply manufacturer’s contacted express interest in participating to the effort

• Benefits of common powering solutions:
  – Shared development efforts and related NRE costs
  – All take advantage of other’s experiences from the specification phase through out the final product qualification
  – Higher volumes - Production cost reduced
  – Less specific equipment in operation - Easier maintenance, common pool of spares
  – Powering becoming a common effort - Less work on a subject which quite often lacks volunteers
Questions / Comments