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Modern high-availability multi-stage power distribution system for the CMS phase-2 upgrade.

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The operation of CMS at the HL-LHC requires an upgrade of the readout electronics. These new modern micro-electronics require power at precise voltages between 1.2V and 2.5V. We will deliver this power using a 3-stage system, comprising AC-DC conversion to 400VDC followed by radiation-tolerant 12V DC-DC power converters feeding radiation-hard point-of-load DC-DC converter. We have studied an industrial 400V AC-DC conversion system, featuring hot-swappable 3kW power modules, stackable up to ˜1MW system depending on the application needs. Our tests demonstrated that the system complied with our requirements, most notably in terms of easy maintainability, high availability and power quality.

Summary (500 words)

CMS operation at the High Luminosity Large Hadron Collider (HL-LHC) conditions requires an upgrade of the readout electronics. The powering scheme must be adapted to match the requirements of the new ASICs and space constraints imposed on detector services.

A common powering system is being developed for the CMS Electromagnetic Calorimeter Barrel (EB), the MIP Timing Detector (MTD) and the Endcap Calorimeter (EC). It comprises 5052 power channels (60W, 120W, 240W) with a total power of ˜660kW. The scope of the system may be also extended to the Tracker detector application. The modern detector electronics require precise voltages between 1.2V and 2.5V. Power will be delivered using a 3-stage voltage conversion.

The first stage is in the radiation-free service cavern, 140m away from the front-end electronics. It converts 230V AC input into 400 VDC employing commercial components and a dedicated fanout system, providing fused power in chunks of 8 kW. The choice of 400V DC as an intermediate voltage was driven by the rapidly growing market of high-availability systems used in the data centers where continuous operation is a crucial requirement.

The second stage uses ˜12V DC-DC converters providing power chunks of 60W to 240W. This stage is located in the experimental cavern, to limit ohmic losses in cables providing power to the volume of the detector. Due to moderately harsh environment, these devices are radiation and magnetic field tolerant (up to 30Gy, 10ˆ13 neutrons/cm2 (1 MeV eq.), 2x10ˆ11 HEH/cm2, 120mT).

Eventually, point-of-load DC-DC converters are embedded into the detector. These ASICs, called bPOL12V [1][2], are the final stage that provides appropriate voltages for sensitive micro-electronics in harsh radiation and magnetic field environment.

A comprehensive study was carried out on the first conversion stage developed by Eltek and its results will be presented in this contribution. The device under test was composed of many 3 kW modules that may be stacked together to build a high-power busbar, that may carry up to 1 MW of power. Failure of one of the modules does not affect the output voltage and the damaged module may be exchanged in operation. Additional advantages of these systems are relatively low-cost and high conversion efficiency, above 95%.

Electrical characterization of the mentioned system has been performed. It includes steady-state operation, as well as transients generated by the system in various real-life scenarios, i.e. module removal, module insertion, start-up of the system, controller failure.

Results obtained are assuring that the use of such a system as a first conversion step is an optimal choice for various criteria, discussed in this contribution. The use of the AC-DC system has a great potential to be extended for other power consumers along the LHC circle or in other particle physics applications.

References:

[1] Federico Faccio et al. "The bPOL12V DCDC converter for HL-LHC trackers: towards production readiness" , TWEPP 2019

[2] bPOL12V v6 datasheet: https://espace.cern.ch/project-DCDC-new/Shared%20Documents/bPOL12V_V6%20datasheet%20V1.3.pdf , accessible as of April 2022

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