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Developments on DC/DC converters for the LHC experiment upgrades

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Prototypes of DC/DC converters were designed and built with the aim of satisfying the foreseen working parameters in the Phase 2 LHC experiments, using both MOSFETs and more recent devices like SiC and GaN transistors. Optimization of their design, based on the comparison between the simulated and measured thermal, electrical and mechanical performance, is in progress, and many improvements are under implementation.
Many tens of samples, chosen among the devices commercially available in the three different technologies, Si, SiC and GaN, were electrically characterized and tested under gammas, neutron, proton and heavy ion radiation, also using a combined run method.

Summary

Since three years the Apollo collaboration is developing technologies for designing high power DC/DC converters and high current Point of Loads (POL) able to cope with the electrical, mechanical and environmental requirements of the upgrades planned by the LHC experiments for both Phase 1 and Phase 2[1].
Several improvements on the power converter prototype described in [1] were implemented, mainly:
- the planar transformer made by multilayer printed circuit boards was replaced by a similar one made of thicker copper windings to better dissipate the internal heat and reduce copper losses;
- a specific heat sink was simulated, designed and manufactured, in order to remove most of the generated heat using a liquid coolant;
- a better thermal coupling between the transformer and the heat sink and a more robust connection to the external cables, which contributed to decrease the internal temperature of the transformer.

The final paper will report on the detailed design and on the performed measurements, also including other improvements in progress like the replacements of controller and auxiliary converter.
High current POLs (Iout ≥ 20 A) based on Gallium Nitride devices (GaNs) are under evaluation. Several GaNs were electrically characterized using a dynamic test bench to be able to contemporary measure the device currents and voltages during the switching time on inductive loads. They were also irradiated with protons at 7 MeV, using a Van der Graaf accelerator available at the INFN Laboratori Nazionali di Legnaro, up to 4*10ˆ14 proton/cmˆ2, with good results.
The design of POLs with GaNs in the output stage is in progress, using a standard Buck topology, and its characterization will be shown.
Studies on core materials able to work in B field > 1 T without saturating is still in progress. With two starting materials and six binder combinations, twelve kinds of feedstock were developed and tested. Debinding and sintering in reducing atmosphere are the critical steps towards the target, and some optimization is still needed.
Device performance under radiation is a key feature of the project. Last year, commercial 200V/20A power MOSFETs were extensively tested with combined runs, first using a 60Co source, available at the ENEA Calliope facility in Casaccia, up to 9.6 kGy, and after some weeks the same samples were irradiated with a 79Br heavy ion beam at 150 MeV. The degradation of the gate oxide induced by gammas severely reduces the SEE sensitivity of the devices, and some samples failed because of a SEGR taking place at a lower voltage.
Power MOSFETs and Silicon on Carbide devices (SiCs) were also irradiated with neutrons, up to 6*10ˆ12 1MeV equivalent n/cmˆ2, at the ENEA Tapiro facility in Casaccia. Irradiation with protons of the same type of devices is still in progress at the Cyclotron facility of the INFN Laboratori Nazionali del Sud, Catania.
Combined runs on gammas and heavy ions are in progress for GaNs, while further neutron and proton tests are planned for summer 2013.

[1] M. Alderighi et al.: Power converters for future LHC experiments, TWEPP2011

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