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Radiation tolerant conditioning electronics for vacuum measurements

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Vacuum in the ARCs of the LHC is crucial to minimize beam –gas interactions and to assure thermal insulation of cryostats and helium distribution lines. Several hundred of sensors with their associated conditioning electronics are installed across the ARCs for both beam and insulation vacuum measurements. Simulations predict that radiation levels will greatly increase during HL-LHC era. Therefore, new radiation tolerant conditioning electronics for vacuum measurements are required to withstand such conditions. This paper describes the design of these new electronics, their qualification tests and implementation within the vacuum controls architecture foreseen during the long shutdowns of the LHC.

Summary

In the LHC ARCs, three types of pressure sensors with their dedicated conditioning electronics are used to cover the whole pressure range: the membrane, the Pirani and the Penning gauges.
Simulations predict that the Total-Ionization-Dose (TID) in the LHC ARCs will reach 90 to 200 Gy by the end of HL-LHC era. The present system is not designed to withstand such doses. Therefore, new radiation tolerant electronics have been developed, based on Commercial Off-The-Self components (COTS), aiming to withstand 500 Gy.
The membrane gauge conditioning electronics provides a stabilized symmetrical power supply to the piezoresistive Wheatstone bridge of the gauge. The input stage filters and conditions the bridge signal to 0-10V.
The Pirani gauge conditioning electronics supplies the filament of the gauge through a self-powered Wheatstone bridge. It maintains the temperature of the filament to a constant value for the whole pressure range, providing a non-linear voltage as a function of the pressure. The other stages are used for calibration, linearization, filtering and condition the signal to 0-10V.
The Penning gauge conditioning electronics generates a high voltage of 3kV through a DC/DC converter based on a Royer oscillator, a high frequency voltage set-up transformer and a voltage multiplier. The ionization current from the gauge (from 1nA to 100uA) is converted to voltage with a logarithmic (LOG) amplifier with a gain of 1V/decade of current. A second stage filters and conditions the signal to 0-10V.
The 0-10V read-out of each conditioning electronics is converted to 4-20mA signal and transmitted to the acquisition system installed in radiation free areas, up to 1km distance.
Each conditioning electronics is designed in a modular 3U EUROPA format card. Up to 9 cards can be inserted in a crate and are powered by two redundant linear power supply cards, distributing the +/- 24VDC.
Automatic tests have been carried out to characterize their functional responses under normal conditions, thermal cycles and ionizing radiations.
A dedicated control system based on industrial programmable controllers (PLC) and WinCCOA has been developed for this purpose. It can sample up to 100 analog channels every second, control Source-Meter-Units, archive the data in a server database and sends alarms in case of failure.
Qualification under radiations has been performed in three phases: COTS tests and screening, critical subsystem and full system tests.
18 COTS have been tested at Paul-Scherrer-Institute (PSI), under a 200 MeV proton beam with a dose rate of 350 Gy/h and a High Energy Hadron (HEH) fluence of 1.1012 cm-2. 15 COTS have been accepted for the

design and specific batches have been ordered for the production.
The LOG stage has been tested at the CO60 facility at CERN (gamma source) up to 500 Gy with different dose rates. In addition, critical sub-systems and full systems were qualified at the CERN High Energy Accelerator Mixed-field (CHARM) facility, which generates a mixed field of secondary particles with wide energy spectra with a HEH fluence of 1.1012 cm-2 and a 1MeV neutron equivalent fluence of 2.1012 cm-2.

Primary authors: Mr CHATZIGEORGIOU, Nikolaos (CERN); Mr KRAKOWSKI, Pawel Wojciech (CERN); Mr PIGNY, Gregory (CERN)

Presenter: Mr CHATZIGEORGIOU, Nikolaos (CERN)

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