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Radiation-Tolerant Custom Made Low Voltage Power Supply System for ATLAS/TileCal Detector

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The Tile Calorimeter front-end electronics of the ATLAS detector is powered by 256 custom-made low voltage power supplies (LVPS) called LVBOX. Each LVBOX contains eight 150W DC/DC single-output modules transforming 200VDC input into various independent low voltage outputs (+3.3V, +/-5V, +/-15V). A local control and communication board using ELMB permits to monitor behavioral parameters (temperatures, Iin, Iout, Vin, Vout, sense lines reading) and trim Vout of each DC/DC module (Brick) using CAN Bus communication. The power supply is water cooled, is capable to survive a total integrated radiation dose of 40krad, and can work in external magnetic field higher than 0.02 Tesla. The LVPS is now manufactured in 256 production units.The 200VDC input voltage for these LVBOXes are delivered from 22 bulk power supplies HPS1 located in USA15 control room. Sixty-four auxiliary control and power supply boards (AUX Board) in the same control room are required to give power for the LVBOX monitoring and control circuits. Four LVPS Interlock Boards are capable to switch off all LVPS and HPS1 supplies in case of water cooling system leak or general switch off of the Tile detector.

Summary

LVBOX

The power supply, called LVBOX, is mounted in the vicinity of Tile Calorimeter detector modules (drawers) inside so called FINGERS [1]. Each LVBOX contains eight independent DC/DC converters - bricks (3.3VDIG, +5VMB, -5VMB, +5VDIG, +15VMB, +5VHV, +15VHV, and -15VHV), so called ELMB Motherboard, ELMB plug-in board [2], 200VDC distribution Fuse-Board, internal cable set, and chassis and water cooled heatsink. The ELMB Motherboard and ELMB module are connected to DC/DC converters and permit remote PC monitoring of their behavioral parameters (temperatures, Iin, Iout, Vin, Vout, DIG and MB side sense line voltages) and set trimming of Vout. Start-up sequence of LVBOX is carried out in 3 groups of bricks[5]. HV or DIG side brick group shutdowns are triggered by most critical power lines: -5VMB, +15VMB, and -15VHV. The LVBOX is exposed to radiation and magnetic field in the ATLAS cavern. The Tile LVPS system is computer managed by the Detector Control System (DCS) software through a CAN Bus line that communicates with the local ELMB of each power supply. The LVBOX of each Tile detector module has to deliver average power of 300W. Production of final 256 units started at CERN in January 2007.

DC/DC SWITCHING POWER SUPPLY MODULE - “BRICK”

The key component of the LVBOX is a small size (80 x 80 x 30mm), radiation and magnetic field tolerant, single output DC/DC dual transistor synchronous forward converter based on LT1681 chip[6]. Full custom design using only COTS (Commercial Off The Shelf) components and the universal printed circuit board design enabled to select three brick versions of various outputs (+3.3V, +5V, or 15V) by means of only several components change. Brick input voltage is +200VDC due to the radiation derating. The maximum output power from the brick is 150W. The DC/DC converter design enables high efficiency of energy conversion: 72% for 3.3V @10A Iout, 85% for 5V version @10A, and 82 % for 15V version @6A, respectively[3]. Switcher uses the current mode control and has fixed switching frequency of 300kHz. The brick frequency can be synchronized with other DC/DC modules inside LVBOX. In order to start, the brick needs a remote auxiliary Start-Up voltage of +15V coming from the AUX

Board in USA15 control room. Important brick features are active Overcurrent and Overvoltage protection circuitry[5]. Innovative technology of brick cooling (especially of the switching FET power transistors, power inductors and high frequency transformer) was applied by means of custom made Al2O3 ceramic spacers. 2048 bricks plus spares are needed for the LVBOX production.

Brick has integrated remote control and measurement circuitry for both input (Iin/Vin) and output (Iout/Vout) parameters. Moreover, three temperature sensors are also present to control brick cooling. The Vout voltage can be trimmed in range of 15%. This feature enables a remote correction of Vout voltage during radiation degradation of output voltage of LVPS. The trimming, sensing and remote control of the brick are carried out by the ELMB module [2].

Extensive irradiation test campaigns of COTS components and of the brick prototype were performed at PSI, Villigen, CH (protons 2002, 2003, 2004), at CERN (neutron P2B 2004, TCC2 SPS tunnel 2002, 2003 campaigns), Saclay (Co60 gamma test 2003) and at INT Portugal NIEL tests in 2003[3]. Experimental results demonstrated that bricks and ELMB motherboards could work together without problems up to 20krad TID, and survive up to 2.15E+12 n/cm^2 neutron fluency. Bricks radiation tolerance is even higher reaching 35-38krads. Bricks are also designed to be operational in external DC magnetic field without damage. Magnetic field decreases efficiency caused by DC magnetization of the HF transformer ferrite core. Decrease of the DC/DC converter efficiency measured at CERN magnet with external B at 200 Gauss (TILECAL nominal level) was max -1.5%, and at 500 Gauss was -3%.

200VDC BULK POWER SUPPLIES

The input for the Tile power system is 200V DC voltage that is converted from three phase mains 3x230V~. For this purpose 22 custom made bulk power supplies HPS1 are needed. One HPS1 unit contains three 1.7kW power channels delivering 200VDC/8.5A [4], and can power 12 LVBOX power supplies. HPS1 are not radiation tolerant and therefore are deployed in USA15 control room of the ATLAS cavern. They were developed at TESLA Company, Prague, CZ.

AUX BOARD

The Auxiliary (AUX) Board is 6U sized pcb board and generates all auxiliary signals and power voltages for one cluster of 4 LVBOXes. The board consists of 3 x 4 isolated power supplies for the ELMB motherboard (trimmed between 6.8 - 14.5V), for ELMB chip (6.8 - 14.5V) and Start-up signal (15 - 25V) for LVPS bricks. It also contains current sources for LVBOX HV/DIG side remote on/off current loop controls and an interlock circuitry. The board is controlled via ELMB module hosting custom made version of ELMB software. So all AUX boards are creating another CAN bus network and theirs control is embedded into the overall remote control system. The distance between 64 AUX Boards or 22 HPS1 supplies in USA15 room and 256 LVBOXes in the ATLAS cavern varies from 60 to 100 meters depending on the position of particular power supply.

LVPS INTERLOCK BOARD

The LVPS interlock board receives ATLAS DSS cooling interlock signals. In case of interrupted water cooling to the Tile Calorimeter, one LVPS Interlock Board will disable functioning of 64 LVBOXes. It is hardwired together with 16 channels of 200VDC HPS1 bulk power supplies and 16 AUX Boards.

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