POWER SUPPLY SYSTEM FOR THE ATLAS EXPERIMENT: DESIGN SPECIFICATIONS, IMPLEMENTATION, TEST AND FIRST RESULTS

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The planned upgrade of instrumentation sensitivity in the ATLAS experiment of the Large Hadron Collider (LHC), at CERN, calls for a new type of power distribution architecture. Moreover, power supplies require DC-DC power con-

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verters able to work in very hostile environment and maintaining high level of Reliability, Availability, Maintainability and Safety (denoted as RAMS requirements) during the experimental activity. Two main issues need to be discussed: first, electronic devices and equipment must operate in very high background of both charged and neutral particles and high static magnetic field and, second, the increase of the radiation background and the requirements of new front-end electronics are indeed incompatible with the current capability of the actual distribution system. The APOLLO R&D collaboration, funded by the Italian Istituto Nazionale di Fisica Nucleare (INFN), aims to study dedicated topologies of both distribution system and DC-DC power converters and to design, build and test demonstrators, developing the needed technology for the industrialization phase. The collaboration has designed a 3kW, 280V-12V converter (MC) based on the Switch in Line architecture (SIL), a DC to DC phase-shifted converter characterized by a disposition in line of the MOSFETs with good soft switching performances, and in the last year many steps have been taken to enhance the power dissipation and the reliability and to improve the general features of the designed converter. In particular a new water heat sink was designed on the basis of TFD simulation accounting for the layout of the specific converter. Experimental activities in order to characterize both thermal and electrical features of the MC confirm the correctness of the adopted design criteria.

Keywords: Power Supply; Power Converter; Reliability; LHC.

1. Introduction

The Large Hadron Collider (LHC) is, nowadays, the world’s largest and highest-energy particle operative accelerator, built by the European Organization for Nuclear Research (CERN) able to extends the frontiers of particle physics thanks to its high energy and luminosity. The Phase-2 upgrade of the LHC is planned to take place during the long shutdown of the year 2022 when the detectors will be upgraded or substituted. An increase of the radiation background will cause the accumulation of a higher Total Ionizing Dose (TID). Furthermore a significant increase of power demand of the detectors implies a complete re-design of the power distribution system, water cooling and very stringent thermal constraints in order to maximize both performances and RAMS requirements.

2. The Main Converter

The Main Converter is based on a Switch in Line Converter (SIL) topology where the circuit consists in a series connected half bridge converter as described in previous papers. The first, of three in 2003 redundancy configuration, implemented prototype able to deliver 1.5 kW i.e. 125 A at 12 V is depicted in Fig. 1 (parallel connection is possible because SILC topology acts like a controlled current generator).
In order to improve the performance and the reliability of the converter in the last year the prototype has been deeply modified: the planar transformer PCBs has been replaced with copper windings separated with Kapton sheets, a specific cold plate has been designed, simulated, tested and manufactured (Fig. 2), the thermal coupling between the transformer and the cold plate has been re-designed and improved, the connections to the external power cables have been improved and, finally, the auxiliary power supply and the controller have been replaced. In particular, the cold plate has been designed taking into account the necessity of dissipation in proximity of single devices in such a way to have a power dissipation that

Table 1. Module devices: description and dissipated power (output power: 1.2 kW).

<table>
<thead>
<tr>
<th>N</th>
<th>Device</th>
<th>$P_d$ (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Planar transformer - core</td>
<td>130</td>
</tr>
<tr>
<td>2</td>
<td>Planar transformer - windings</td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>Diodes (ISOTOP)</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Primary - MOSFETs (TO247)</td>
<td>18</td>
</tr>
<tr>
<td>5</td>
<td>Primary - inductor core</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Primary - inductor windings</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Auxiliary - MOSFET (TO247)</td>
<td>0.2</td>
</tr>
<tr>
<td>8</td>
<td>Auxiliary - MOSFET (D2PAK)</td>
<td>0.2</td>
</tr>
<tr>
<td>9</td>
<td>Auxiliary - transformer core</td>
<td>0.5</td>
</tr>
<tr>
<td>10</td>
<td>Auxiliary - transformer windings</td>
<td>0.5</td>
</tr>
<tr>
<td>11</td>
<td>Capacitors and other devices</td>
<td>4.5</td>
</tr>
<tr>
<td>12</td>
<td>Copper traces at secondary</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td><strong>Total power dissipation</strong></td>
<td><strong>246.4</strong></td>
</tr>
</tbody>
</table>
3. Magnetic field test of a commercial DC-DC converter

An integrated DC-DC step-down converter by Linear Technologies (LTM4619) has been tested in order to check its magnetic field tolerance. Test have been carried out at the LASA, a center for research and development in the fields of accelerators and of superconductivity of University of Milan and INFN. The tested evaluation board is shown in the following Fig. 3. The tests have been carried out changing the position of the evaluation board in order to apply the magnetic field in different directions (Fig. 3). The experimental setup is depicted in Fig. 4.

The two outputs of the evaluation board are both configured to provide an output voltage of 1.8 V on a nominal load of 0.6 Ω. The current supplied is therefore equal to 3 A per output, 5.4 W. The board power input was supplied at 20 V.

It was also added a heat sink which enabled to maintain the module at approximately 35 °C. This allows the device to work as much as possible at the conditions of nominal efficiency. The tests have been carried out with the applied magnetic field in three directions.

The best performance was obtained with the magnetic field orthogonal to the device plane, up to about 0.4 T. The worst performance was observed with the magnetic field parallel to the device and with direction right to left, as depicted in Fig. 5.
4. Conclusions

The designed prototype has proved capable of providing the performance required by the design specifications. Further tests will be conducted with the aim to verify both the radiation and magnetic field effects. Some results on a commercial POL which showed a good behavior until 0.2 – 0.4 T have been also presented.

References


