ATLAS NSW Project

Intermediate Conversion Stage for the Low Voltage System of the ATLAS New Small Wheel Project

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This document is the base for technical discussions with selected firms in the fourth quarter of 2016, for a contract to be awarded at the end of 2016. The selected firms will be commissioned to build a demonstrator module, and upon the successful validation of that demonstrator there will be a competitive tender to assign the production of the full quantity of modules.

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Distribution List

History of Changes			
Rev. No.	*Date*	*Pages*	*Description of changes*

1. INTRODUCTION

1.1 *Introduction to ATLAS*

The Large Hadron Collider (LHC) is the largest and most recent accelerator constructed at CERN, the European Organization for Nuclear Research. The LHC accelerates and collides proton beams or heavy ions at unprecedented energies. It is installed in a 27 km circumference tunnel, about 100 m underground.

ATLAS, A Toroidal Lhc ApparatuS (www.atlas.ch), is a particle physics experiment at the Large Hadron Collider. The ATLAS collaboration involves approximately 8,000 participants from 213 institutions in 40 countries. The ATLAS detector is designed and constructed to make new particle discoveries resulting from proton collisions produced by the LHC. ATLAS is located in an underground cavern on the Swiss part of CERN. The experiment is in operation and produces physics results.

The ATLAS detector has a diameter of 25 m and a length of 45 m, and houses many different sub-detectors. It is arranged as a lying cylinder, with subsystems divided into "barrel" and "endcap" regions. In the endcap region are three disk-shaped muon detectors on each side. The innermost disk on each side (known as Small Wheels) will be replaced during the LHC Long Shutdown 2 (2019-20) by the so-called New Small Wheels (hereinafter referred to as "NSW"). The NSW is in a harsh environment, subject to radiation and magnetic fields.

1.2 The New Small Wheel

The NSW is composed of two wheels, one on each side of ATLAS (called A and C) [2]. Each wheel hosts two independent detector systems – MicroMeGaS (hereinafter referred to as "MM"), and small Thin Gas Chambers (hereinafter referred to as "sTGC"). A scheme of a single wheel of the NSW is shown in Figure 1.

The radius of the single wheel is 4.6 m and it will have a weight of about 112 t.

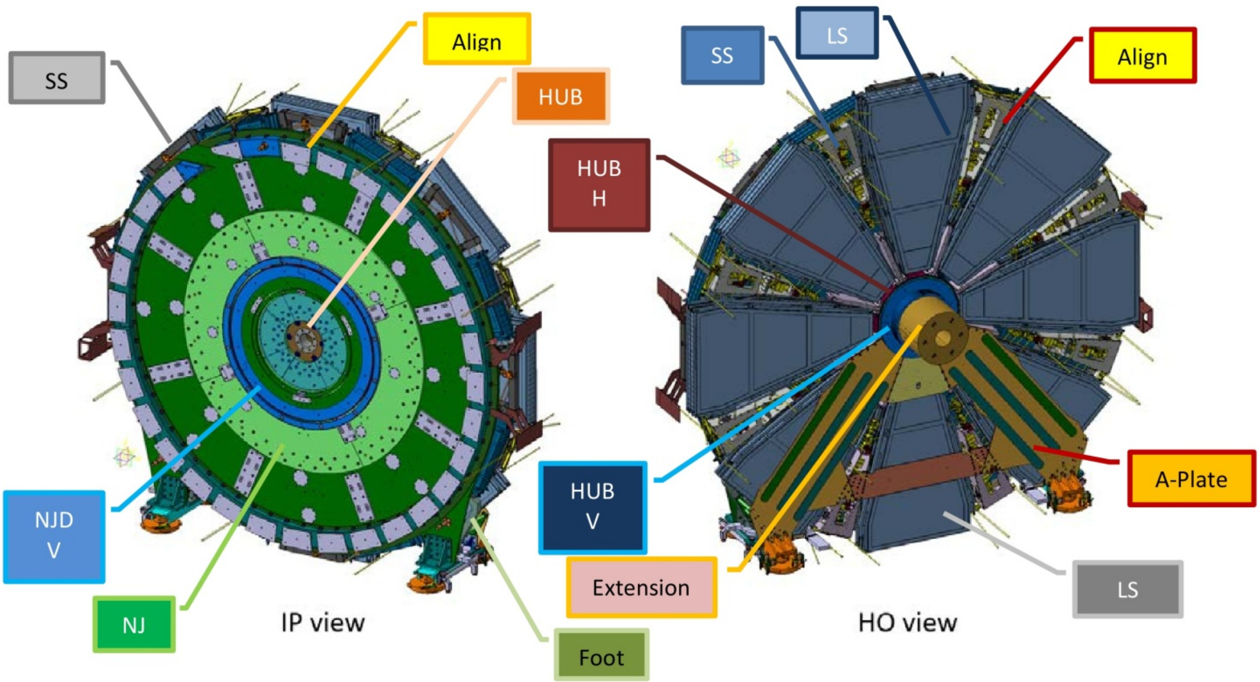

Figure 1: Scheme of one wheel of the NSW.

2. SCOPE OF THIS DOCUMENT

The purpose of this document is to define technical specifications for the supply of an on-detector low-voltage conversion system for the NSW (hereinafter referred to as the "Intermediate Conversion Stage (ICS)". The word "supply" is referred to the deliverable of this document, as specified in 2.1.
Companies selected on the basis of their proven ability of building rad-tolerant LV power supplies will be awarded with a contract to produce a demonstrator module (the "supply") that must meet all technical requirements as specified in the final specifications.
Upon the successful validation of this demonstrators by the NSW Collaboration, the companies will submit their best offer for the full quantity of modules, providing 640 LV channels for the MM system and 448 channels for the sTGC system.

2.1 Deliverables included in the supply

Deliverables are the design and construction of a demonstrator module able to cope with all the technical requirements described in Section 3.

2.2 The demonstrator module

This module has to demonstrate the validity of the design and the selected components and protocols made by the companies. Not necessarily it must be produced with the number of channels specified below. The demonstrator must comply with the following general requirements:
- minimal number of channels: 2, where each channel has to cope with the technical requirements specified in chapter 3;
- the cooling system and the monitoring/control communications must be expandable by design up to 8 channels;
- the dimensions of the single channel must be compatible with what specified in 3.4 for the 8-channel production module.

2.3 Validaion tests

The NSW collaboration will test the delivered demonstrator modules together with the companies on the basis of the agreed technical requirements, particularly regarding the specified radiation and magnetic field tolerances. At the end of the tests a final report will be written and approved by the NSW collaboration and by the involved companies, giving them the green light to participate to the price enquiry for the final production in case all the requirements will be achieved. The tests will be performed following a protocol that must be agreed in advance by the involved parties.
During the design phase and upon a specific written request, the NSW collaboration is available to organize tests under radiation and in B field of single or multiple parts of the demonstrator, even if not final, and to actively participate to them. These tests will be performed in presence of specialized technical personnel of the applicant company, and the results will be restricted to it.

2.4 Periodic checks during the duration of the contract

Companies must be available for periodic status checks of the NSW contacts during the design and construction phases of the demonstrator. These checks will be held separately for each company either at the company premises or at Cern, and will be required by the NSW contacts at least two weeks in advance every three months from the contract award.

3. TECHNICAL REQUIREMENTS

3.1 The NSW LV system

The 7,500 on-detector electronics boards of the NSW are expected to draw about 110 kW of power in aggregate. The components on these boards require voltages ranging from 1.2V – 2.5 V, which will be provided by integrated DC-DC converters using the CERN FEAST ASIC [3]. These converters operate from an input supply from 5 to 12 VDC. Mechanical and thermal considerations limit the permissible cable bulk and require that the detector be supplied with at least 48 VDC. It is therefore necessary to include a power conversion stage on the detector.

This document is related to the supply of the ICS that will be installed on the detector, accepts at least 48 VDC as input, and provides a maximum of 12 VDC to the on-detector electronics boards. In the following the ICS specifications are described.

3.2 Proposed quantities

It is expected that there will be 640 LV channels (80 modules) for the MM and 384 channels (48 modules) for the sTGC system. All electrical, mechanical, and functional requirements are the same for both. It is intended that each module provides 8 channels as described in the mechanical requirements.

3.3 Requirements

Table 1 lists the required environmental tolerances. The functionality of the supply is summarized in Table 2. The mechanical and electrical requirements are in Table 3 and Table 4, respectively.

Environmental Tolerance	Required Value
Ionizing Radiation	96 Gy
Displacement Damage	$5.8\text{x}10^{12}$ 1-MeV Eq. n/cm^2
Single-Event Fluence	$1.0\text{x}10^{12}$ p/cm^2 (E > 20 MeV)
Magnetic Field	0.5 T

Table 1: Environmental tolerance requirements for the ICS power supply

V_{set}	Local Hardware	FIXED 12.0V +0% - 20%
	Remote Software	NO
I_{set}	Local Hardware	NO
	Remote Software	NO
V_{max}	Local Hardware	FIXED 12.1V
	Remote Software	NO
I_{max}	Local Hardware	FIXED 17.0 A
Trip logic		YES
Overcurrent reaction		Trip when I_{max} is exceeded
Overvoltage reaction		Trip when V_{max} is exceeded
Sense wires		NO
Impedance local adj		NO
Remote Monitoring	V_{out}	YES
	I_{out}	YES
Remote ON/OFF		YES
Cooling	Water Supply	External

Table 2: Functional requirements for each channel of ICS power supply

Module Format	Custom
Maximum height	90 mm (higher must be approved)
Maximum width	200 mm (larger must be approved)
Maximum length	200 mm (longer must be approved)
Channels/module	8
Monitoring / control	Via CAN-Bus or other approved bus
Input connector	TBD
Output connector	TBD
Cooling water connection	TBD

Table 3: Mechanical requirements for the ICS power supply

	Each Channel
V_{in}	48 VDC or higher (up to 300 VDC)
V_{in} tolerance	± 15%
V_{out}	Positive 12 VDC +0% -20%
V_{out} accuracy	1% FS
V_{max}	12.1V
V_{max} accuracy	1%
I_{out} nominal	16 A DC
V_{mon} resolution	< 50 mV
I_{mon} resolution	< 100 mA
V_{mon} precision	± 0.2%
I_{mon} precision	± 0.2%
Trip time	1 s for overcurrent, 0.1 s for overvoltage
Ground	Floating, each channel isolated
Noise level	Maximum 45 dBuA in the range 150 kHz – 500 kHz, 39 dBuA in the range 500 kHz – 30 MHz
Common ripple	< 20 mV_{pp} from 0 – 30 MHz
Differential ripple	< 20 mV_{pp} from 0 – 30 MHz
Minimal resistance between channels	20 kΩ
Minimal resistance between each channel and GND	10 kΩ
Maximal capacitance between channels	50 nF
Maximal capacitance between channel and GND	100 nF
Redundancy	Must allow two channel outputs to be paralleled for redundant supplies
Controls	Remote ON/OFF for each channel
Conversion efficiency	≥ 80% above 50% full load recommended
Nominal output power	190 W

Table 4: Electrical requirements for the ICS power supply

3.4 Design parameters

The supply must comply with the international and CERN standards as reported in chapter 4.
The module will be installed in a confined area and must be water-cooled.
The dimensions of the ICS module should not exceed 200 x 200 x 90 mm^3, including the internal water cooling. Some ICS modules can be housed in a mechanical structure, similar to a crate, which can also host part of the ICS cooling system. As a first approach, the number of ICS modules to be contained in such a crate is four. The crate internal dimensions should not exceed too much the ones of four ICS modules, i.e. 200 x 200 x 360 mm^3. In any case they must be approved by the NSW contacts.
All the electrical connections of the ICS should be placed on one side only, the 200 x 90 mm^2, and the single ICS must be fully extractable from the crate. The cooling connections can be placed either on the same side or on the opposite side.
In case of necessity, the crate dimensions could be extended, by how much will be matter of discussion during the design phase of the prototype.

Controls and monitors must be available remotely. The supply must be accessible either by CAN-Bus, or other bus approved by the NSW contacts, via a provided OPC UA Server.
The communications circuitry may be located externally to the supply if this subsystem requires relaxed radiation and B field tolerance criteria.

3.4.1 Set voltage

The output voltage must be 12V with a hardware regulation of +0% -20%. Under all circumstances the output voltage must not exceed 12.1V.

3.4.2 Monitoring

The parameters V_{out} and I_{out} must be monitored. Voltage and current must have a resolution of 50 mV and 100 mA, respectively, or better. The required precision is 0.5 % for both parameters.

3.4.3 Controls

Each channel must allow individual ON/OFF remote control.

3.4.4 Noise spectrum

It is defined, together with its measurement setup, in IEEE 1515 § 4.11.1 and following:

- Maximum noise level must be smaller than 45 dBuA in the range 150 kHz ÷ 500 kHz;
- Maximum noise level must be smaller than 39 dBuA in the range 500 kHz ÷ 30 MHz[1].

3.4.5 Ripple

It is defined, together with its measurement setup, in IEEE 1515 § 4.5 and following:

- Differential ripple must be smaller than 20 mV_{pp} in the range 0 ÷ 30 MHz;
- Common ripple must be smaller than 20 mV_{pp} in the range 0 ÷ 30 MHz.

3.4.6 Trip logic

The trip of overcurrent, when the I_{max} current setting is exceeded, should have a time delay of 1 s maximum. The trip of overvoltage, when the V_{max} voltage setting is exceeded, must have a time delay of 0.1 s maximum. Both values are set in hardware.

3.4.7 Overcurrent

Action: channel will trip.

3.4.8 Overvoltage

Action: channel will trip.

3.4.9 Sense wires

Not needed.

3.4.10 Impedance control

No local adjustment needed.

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*[1] Levels taken from IEC CISPR 22, section 5.1, table 1, for Class A (non-domestic) equipment, Quasi-Peak values traduced from dBuV to dBuA using 50 Ohm impedance (using correction factor 20*Log 50).*

IEC CISPR 22 is used according to document ATC-TE-IP-0001: ATLAS EMC Policy.

Method and apparatus described in IEC CISPR 16.

3.4.11 Communications

It must be decoupled via opto-couplers with $V_{breakdown}$ > 100 V.

3.4.12 Ground

It must be floating and isolated for each channel. The tolerated voltage difference between channels and between each channel and Earth should be greater than 50 V. Galvanic isolation can be used, if demonstrated that it works in the environment listed in Table 1.

3.4.13 Minimal resistance between channels and between channel and ground

It should be higher than 20 kΩ between channel and channel, and higher than 10 kΩ between each channel and ground.

3.4.14 Maximal capacitance between channels and between channel and ground

It should be lower than 50 nF between channel and channel, and lower than 100 nF between each channel and ground.

3.4.15 Redundancy

The output stage of each channel must be designed so that it can be put in parallel with another output channel, increasing the total load current to 32 A DC nominal.

3.4.16 Conversion efficiency

It must be at least 80% above 50% full load. This value should be the target, and is recommended.

3.4.17 Power consumption

The nominal output power supplied by each channel must be 190 W.

4. STANDARDS

The ICS prototype shall comply with relevant professional and CERN standards and codes including the following:

- Safety standards:
  - IEC 62477-1, part 1
  - IEC 61204-7, part 7
  - CERN IS-23 and IS-41
- Fast transient and surge immunity:
  - EN61000-4-4 and EN61000-4-5
- EMC compliance:
  - EN61000-4-2, EN61000-4-3, EN61000-4-6, EN61000-4-8, EN61000-4-11
  - CISPR22 (EN55022) Class B and CISPR24 (EN55024)
- ROHS compliance:
  - Directive 2011/65/EU
- CE European marking and related regulations

5. NSW CONTACTS

Persons to contact for technical matters:

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6. PERFORMANCE OF THE CONTRACT

6.1 Delivery schedule

The contractor will be asked to specify in the offer the delivery time of the prototype. In any case this time cannot exceed 50 weeks from the contract award.

7. BIBLIOGRAPHY

[1] Airapetian, A.; et al, *ATLAS: Detector and Physics Performance*, Volume 1, 1999.
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[3] http://project-dcdc.web.cern.ch/project-DCDC/