Power Supply for the MDT Detector of the ATLAS Experiment.

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Abstract

In this paper, the problem of the Low Voltage (LV) and High Voltage (HV) power supply distribution of the MDT (Monitored Drift Tubes) detector is addressed. Due to the high number of channels (1168 for low voltage and twice for high voltage) involved and to the dimension of the apparatus, these power supply systems are very complicated. These are composed mainly of three parts: a power generator, a system controller and an active distributor. The first two parts will be placed in the cavern close to the experimental area, so they are subjected to standard environmental conditions. The third part (the active distributor) will be placed in the experimental area on the platforms just outside the detector, in this case the environmental conditions are more severe, due to the presence of magnetic field (about 800 Gauss) and radiations. In the following we present the design specifications and tests for the power supply systems.

I. The ATLAS Muon Spectrometer

In this section, the ATLAS Muon spectrometer layout, the MDT chamber description and the environmental condition in the experimental area, are briefly introduced.

A. Muon Spectrometer Layout

The ATLAS Muon spectrometer is composed of 1172 MDT chambers in total, (see, MDT layout Q rev. 13): 656 in the Barrel and 516 in the Endcap region (Figure 1).

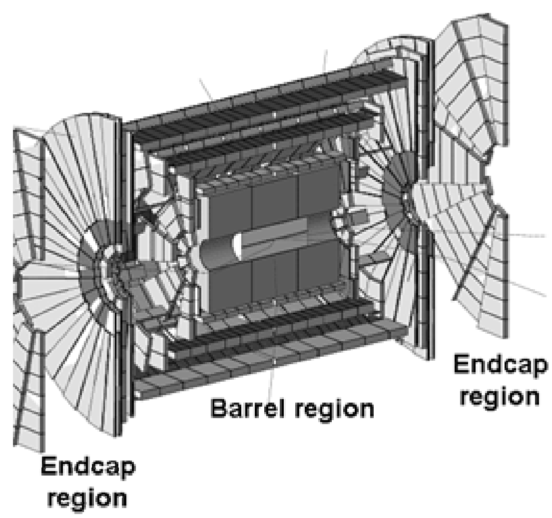

Figure 1: ATLAS muon spectrometer layout.

It is subdivided into 16 sectors both in the Barrel part and in the Endcap, each sector covering an angle of 22.5 degree, (Figure 2). Moreover, this detector is divided in two symmetric sides with respect to the interaction point, the side A and side C.

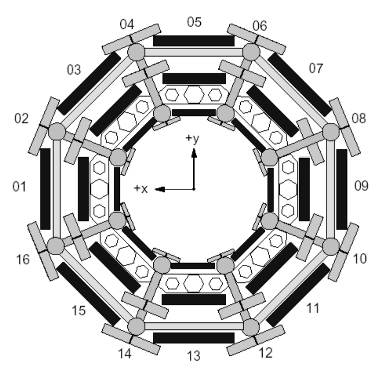

Figure 2: Muon spectrometer sectors.

The MDT chambers [3] are composed of two multilayers separated by an aluminium frame called spacer, (Figure 3). Each multilayer is made, depending on the chamber type, of 3 or 4 layers of drift tubes each with 3 cm diameter, with lengths ranging from 1.5 to 6 meters. The drift gas is composed of Argon (93%) and CO_2 (7%) and has been chosen mainly because of its favourable ageing properties in the LHC environment. The working pressure of the tubes is 3 bar absolute.

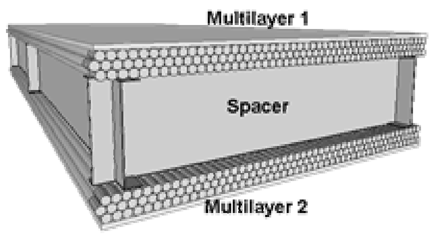

Figure 3: Three layer barrel MDT chamber.

B. ATLAS Muon Spectrometer Environment

The ATLAS detector is installed in a cavern about 90 meters below the earth surface. This cavern is the experimental area and is called UX15, (Figure 4). The environmental conditions in this area are severe due to the presence of radiation and magnetic fields, whose values on the platforms just around the Barrel and Endcap, where the electronic racks will be installed, are reported in table 1.

Table 1: UX15 environment parameters.

Working temperature range	18 to 28˚C	
Working humidity range	40 to 60 %RH	
Magnetic field	800 Gauss	
Radiation background over 10 years (all safety factors are included)	TID	18 KRad
	NIEL	1.2 10^{12} n/cm^2
	SEE	2.6 10^{11} h/cm^2

Table 1 show that in the UX15 cavern, just around the detector, we have a quite high value of magnetic field, about 800 Gauss. This can be a problem for electronic components such as transformers or inductors with ferromagnetic coils and electric motors used in cooling fans. These components need to be carefully designed. Moreover, due to the presence of radiation the electronic components and boards that will be mounted in UX15 need to be radiation tolerant; and their certification is mandatory.

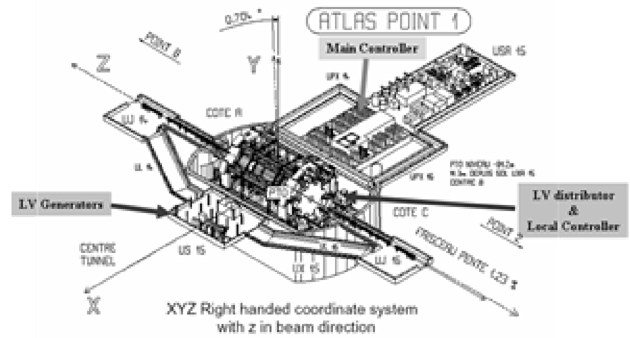

Figure 4: ATLAS cavern system.

The ATLAS area consists of other two caverns in which the control and data collection electronics and part of the power supply system will be mounted. These caverns are called US15 and USA15, see (Figure 4); in these two areas the standard environmental conditions are displayed in Table 2.

Table 2: US15 and USA15 environment parameters.

Working temperature range	18 to 28˚C
Working humidity range	40 to 60% RH
Magnetic field	10^{-3}T max
Radiation background	Negligible

II. HV AND LV DISTRIBUTION, FRONT-END AND READOUT ELECTRONICS.

Each MDT chamber is divided into two sides: the HV side where the high voltage is applied to the chamber and the readout side where the particle generated signals are collected and processed. Low voltage and high voltage channel specifications are illustrated in this section.

A. HV distribution specifications.

The working voltage for a MDT chamber is 3080V, and the maximum current requirement with LHC at full luminosity is about 0.7mA (depending on the size and position of the chamber). HV is distributed to the chamber by means of electronic boards called hedgehogs. The circuit of these boards is essentially a passive network of resistors and capacitors needed to match the impedance and filter the high voltage.

Each layer has its own HV channel, so one chamber needs 6 or 8 (depending on chamber type) HV channels. The HV to each layer is supplied via an on chamber HV splitter that splits two HV input channels (one for each multilayer) into 6 or 8 channels, that is, one for each layer.

In Table 3 the HV voltage and current needed for a MDT chamber are summarized.

Table 3: MDT chamber HV voltage and current

	V oltage [V]	Current [mA]	Power [W]
HV	3080	0.7 (max)	2.16 (max)

B. LV distribution specifications.

Signals coming from tubes are collected by front-end electronics boards called mezzanine, installed on the readout hedgehog.

Each mezzanine card, (Figure 5) collects and processes signals coming from 24 tubes of different layers. They are equipped with 3 amplifier–shaper-and-discriminator chip (ASD [1]), and with a TDC chip. Therefore, each mezzanine card is divided into an analog and a digital part which are supplied through two separate 3.3V low dropout voltage regulators. One of the advantages of putting voltage regulators on the front-end board is that, due to the high value (100µF) input and output capacitance, they filter the input voltage and contribute to the noise reduction on the low voltage power supply line.

Each mezzanine board needs 5V of input voltage and adsorb about 400mA of current for a total power of 2W.

Another fundamental part of the on-chamber electronics is the CSM (Chamber Service Module [2]). This is a digital board that multiplexes data coming from the mezzanines and sends them to the off-chamber electronics via optical fibre. As the mezzanine, even the CSM is equipped with a low dropout voltage regulator. It needs 5V and about 2A of current to work, for a total power of 10 W.

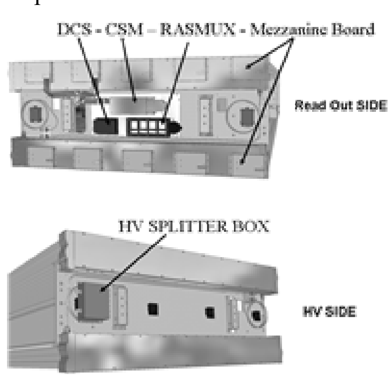

Figure 5: MDT chamber electronics on the readout and HV sides.

In Table 4, the LV voltage and current needed for the on-chamber electronic boards are summarized.

Table 4: MDT chamber LV voltage and current

	Tension [V]	Current [A]	Power [W]
Mezzanine Board	5	0.4	2
CSM	5	2	10

DCS and alignment electronics (RASMUX, see Figure 4), have a different power supply systems with respect to that of the front-end and readout electronics, and are not described in this paper.

C. Complete ATLAS Muon Spectrometer Power Supply Specifications.

From the point of view of the power supply the MDT system is composed of 1168 chambers.

Considering the values reported in Tables 3 and 4 the total power consumption of the Muon spectrometer is reported in Table 5.

Table 5: Power consumption of MDT chambers

	Tension [V]	Current [A]	Power [W]
HV	3080	0.82	2526
LV	5	8260	41300

III. HIGH VOLTAGE AND LOW VOLTAGE POWER SUPPLY SYSTEMS.

The proposed architecture of the two power supply systems is essentially the same. It is composed of three parts:

- the main power generator;
- the main controller;
- the local distributor.

The main power generator is the part of the system that supplies the power to the local distributors (different for low voltage and high voltage). Distributors are active modules, base on DC-DC converters, that convert the input voltage into the high voltage needed for chamber polarization and the low voltage needed to the front-end and readout electronics. All the power supply system is remote controlled by the main controller that monitors the status of the high voltage and low voltage channels.

These three parts will be installed in the three main underground caverns in the ATLAS experimental area, as shown in Figure 6. In particular the LV and HV local distributors are located in the experimental area, UX15, on the platforms just outside the detector. This choice has the advantage of reducing the cable length, but has the drawback that, in this area, there are radiation and magnetic field. Then it is not possible to use standard commercial power supply system, and electronics certified for radiation tolerance and magnetic field is needed.

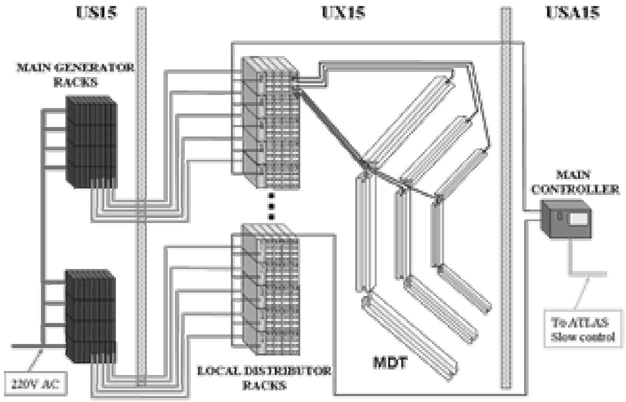

Figure 6: Architecture of the power supply system.

The main generator will be placed in the US15 area, that has standard environmental condition; allowing the use of commercial power generators. Also the main controller is placed in a safety area, USA15 cavern.

A. Main power generator.

To limit the power dissipation in US15 cavern, the main power generator has to be a switching power supply. The input line is the standard 220 or 380 AC lines, while the output is a DC voltage whose value depends on the input voltage required by the local distributor. This system is composed of one module for each distributor crate, so that each module has to supply about 3KW of power. Due to the length of the cables (about 120m), that connect the main generator modules to the local distributor, sense wire cannot be used. The main power generator will be completely remote controlled with all the necessary protections (against over voltage, over current, over temperature, etc…). The cooling of this system will be done by fans mounted directly on each module.

B. Local distributors.

The local distributors are subdivided into HV and LV modules that are based essentially on DC-DC converters. As stated before they are mounted in racks on the platforms outside the detector, so they have to be radiation tolerant and magnetic field insensitive.

Table 6: LV distributor specifications

Adj. Vout on load	6V max val.	5V nom. Val.
Iout on load	20A max. val.	15A nom. val.
Diff. ripple	<20mVpp	
Vset range	0 – 6V	
Iset range	0 - 20A	
Floating ground	Yes	

Table 7: HV distributor specifications

Adj. Vout on load	4000V max val.	3080V nom. Val.
Iout on load	0.001A max. val.	0.001A nom. val.
Diff. ripple	<20mVpp	
Vset range	0 – 4000V	
Iset range	0- 0.001A	
Floating ground	No	

The HV and LV distributor module main specifications are shown in Tables 6 and 7.

These modules have to be remote monitored for the output voltages and currents, and the only remote operation allowed is to switch on and off each single channel or group of channels. All the channel setting will be done manually directly on the module. Reduction of the allowed remote operation provides the cost of the system be lower, but does not compromise their functionality. The maximum cable length from distributors to chambers is about 30m, due to the presence of voltage regulators on mezzanines, sense wire are not necessary.

On the contrary, the HV modules are completely remotely controlled and monitored.

The cooling of the local distributors is a critical issue, due to the presence of magnetic field and to the fact that heat dissipation directly into the cavern must be limited. In magnetic field conventional fans do not work, so in order to cool down the distributor crates it is necessary to use special tangential fans with shielded motors and heat exchangers directly in rack; or to use water cooling directly embedded in the distributor modules.

C. Main controller.

The main controller has to monitor all the channel parameters, that is, input and output voltages and currents, over voltages, over currents, etc… It has to be connected to the ATLAS slow control system, so it has to support all needed communication protocols.

IV. CABLING

Cabling of the power supply system is another important issue. Several different types of cables are necessary to connect the various parts of the system. Some types are common for the LV and HV systems, while others are different.

Common cables are the control cables that connect the main controller to the local distributors. These are multi-wire shielded cables. At the present, no precise cable type has been chosen; it depends on the controller type.

Other common cables are those that connect main generators with local distributors. Due to the high current involved and the long distance, we need a cable with a big cross section, in order to reduce the cable power drop. This will be a 4 conductor cable, two conductors for ground and the other two for positive voltage. The cable cross section it is not yet defined.

The cables that connect LV distributors with the on-chamber electronics are 4 wires cables, each wire with a cross section of $4mm^2$, and the external diameter of the cable is 13.4mm. The whole system needs about 30km of this cable, for a total weight of about 14 tons.

Standard RG58 HV cables with diameter of 5.2mm are used to connect HV distributors to the HV splitter boxes mounted on the chambers.

As required by safety rules, all cables must be halogen free and radiation resistant.

V. CONCLUSIONS.

In this paper we have presented the low voltage and high voltage power specifications for the MDT chambers of the ATLAS Muon spectrometer. Due to the presence of magnetic field and radiation in the experimental area, it is very important to take into account the environmental parameters. A common architecture for both low voltage and high voltage systems has been proposed. This is based on a main voltage generator, localized in a non-hostile area, that supplies the local distributors placed on the platforms just outside the detector. The systems will be controlled by the main controller that is interfaced with the ATLAS slow control system.

Test for radiation tolerance and magnetic field are under way for both power supply systems.

Cable type and length needed to connect the various part of the systems have been described as well.

VI. REFERENCES.

[1] Posch,C et al., *MDT-ASD, CMOS front-end for ATLAS MDT*, ATLAS notes, ATL-MUON-2002-003

[2] Binchi, P., *Chamber service module (CSM1) for MDT*, Proceedings of the eighth workshop on Electronics for LHC Experiments, Colmar, France, 9-13 Sep 2002, pages 353-356

[3] *ATLAS muon spectrometer TDR*, CERN/LHCC 97-22