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TECHNICAL SPECIFICATION OF BULK POWER SUPPLY FOR PRIMARY VOLTAGE OF DCDC CONVERTER BOXES OF TILECAL SUBDETECTOR OF ATLAS

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INTRODUCTION

Bulk power supply described by this specification should be a part of power supply system of TILECAL detector, subdetector of ATLAS project build at CERN. Power supply will work as a first stage of dual stage power supply system. Power supply should deliver total power of roughly 110kW to 256 DCDC converter boxes spread around TILECAL detector. DCDC converter boxes will work in radiation environment and electronics supplied by them also. This point is important for design of parameters of bulk power supply.

During the time of operation, which is 10 years the current consumption will increase due to the total dose effect in powered electronics. Then the safety margin was designed as 100% above nominal value. This will cover not only radiation effect but also other changes of power consumption of the system. Bulk supply itself will be placed in shielded and air-conditioned area so then it avoids the problems with environment.

Supposing that bulk supply design will use switching converter we could estimate the efficiency, size and also deployment and cooling in the standard ATLAS racks. According to some examples the efficiency could be 90% and could be possible to build-in 3 outputs to the standard 19" crate with 4U height. The crate will not be equipped by independent cooling system or fans. Cooling will be performed by rack, which has sufficient capability in case of those estimated parameters.

Following table shows complete power consumption estimation overview of the power supply system.

Safety margin [%]	100				
Load sections	**Voltage**	**Current**	**Power**	**Efficiency**	**Input power**
Hvside	5.00	1.00	5.00	85.00	5.88
	15.00	1.00	15.00	85.00	17.65
	-15.00	4.00	60.00	85.00	70.59
3in1	5.00	20.00	100.00	85.00	117.65
	-5.00	10.00	50.00	85.00	58.82
	15.00	1.00	15.00	85.00	17.65
Digitizer	5.00	10.00	50.00	85.00	58.82
	3.30	10.00	33.00	85.00	38.82
Output power / box [W]			328.00		385.88
Parameters for cabling					
Input voltage [V]	200.00				
Input current [A]	1.93				
Fingers connected to one bulk supply-daisy chained fingers	4.00				
Cable resistance					
Wire crossection [mm^2]	2.50				
Resistivity of cooper [Ohm m]	0.0220				
Length [m]	300.00				
Resistance [Ohm]	2.64				
Power loses in cable [W]	157.24	with connected	4.00	fingers	
USA15 output power / cable [W]	1700.77				
Total number of cables needed (no spares)	64.00				
TILECAL Power supply system efficiency profile	Power [W]	% of total input power	% loses		
USA15 input power / TILECAL	120944	100.00			
Bulk supply loses	12094		-10.00		
USA15 output power -> TILECAL in UX15	108849	90.00			
Cable loses	10064		-8.32		
Power loses in converter box	14818		-12.25		
Output power	83968	69.43			

The top of table shows power consumpion of each from 8 output channels. Current consumption has already 100% safety margin. Then is computed total power for one DCDC converter box as 385W. Following part of table computes power loses due to cable resistance. Contact losses are not taken in account. Topology should ensure powering of 4 DCDC converter boxes via one cable. It means 64 cables over whole system to 256 boxes. Power loses in one cable should be ~ 160W for maximum load.

Then could be estimated maximum output power from one channel of bulk power supply which is 1700W. Last part of table shows total consumption and overall efficiency of power supply system.

The operational nominal output power will be roughly the half of maximum. According to the informations from radiation test of TILECAL elecronics the value of outptut power will increase during the years of operation maximally by 30%.

ELECTRICAL PARAMETERS

Most important parameters were estimated from previous table and are dependent on the real parameters of the cabling system and character of the load. Anyway following table fits first estimation of parameters.

Parameter	Value	Unit	Conditions
Number of channels inside crate	3		
Maximum outptut power/channel	1700	W	
Nominal output power/channel	900	W	
Efficiency	~90	%	
Nominal output voltage	200	V	
Trim of output voltage	+20/-0	%	Remote controlled
Regulation	<0.5	%	Load from 225W to 1700W I.e. from 13.2% to 100% of full load
Short term stability	<0.5	%	
Long term stability	<0.5	%	
Ripple+noise	100	mVpp	
Maximum outptut current	8.5	A	Trim 0%
	7	A	Trim +20%
Nominal output current	4.5	A	
Minimum output working current	1.125	A	Below this current the stability and regulation parameters are not sure
Load characteristics	Rectangle CV/CC		Current limit on maximum current see section Load characteristic & dynamic behavior
Dynamic behavior			
Response to load change	max. +4	V	100% ->0% of load change
	min. -10	V	0% ->100% of load change
Input voltage	380	V	3phase,50Hz, +20/-10%

Note 1: See also section Load characteristic & dynamic behaviour

Description of the load

The load of power supply will be 32 DCDC converters connected in parallel to the output of the supply. In between output and converters will be roughly 150m of cable.

Next request for the prototype is to ensure that voltage is in the specified range at the end of cable. This request is connected with the trim of voltage and preferred solutions are sense wires or cable compensation slope (negative resistance) of load characteristics. In this case there must be the specified trim – remotely controlled – which will set a drop of voltage. Supply then will change its output voltage according to the output current to compensate load changes.

Output voltage should be trimable from 0 to +20% of nominal value. It allows to the user to compensate voltage drop on the cable and contacts. Maximum output power is designed with sufficient safety margin so in case of +20% of trim the maximum output power stays constant. It means that maximum output current will then be lower.

Load characteristic & dynamic behaviour

For slow load changes (manual regulation of the load) must be the load characteristic of supply rectangle shaped to have CV till maximum current. Then this characteristic changes to CC type and keeps the maximum current anyway the output voltage is 0 in case the protection is disabled.

In case of trim of output voltage the maximum current follows hyperbolic curve of maximum output power 1700W.

Concerning dynamic behaviour of the supply we need response which will ensure that output voltage will never go over nominal voltage + trim/compensation of about + 4V. The speed of response is not so critical.

Start procedure supposes sequential start of supply and following DCDC converter boxes. It means that start load for supply will be only capacitive with the value > 100uF. Then the supply should charge this capacitance. DC current consumption in this phase is close to zero. DCDC converter boxes will be remotely started then after. There is a possibility to have any combination of power from zero to nominal value in steps roughly by 200W. In case of any of the transients the voltage must be kept in the specified region. DCDC converter is able to overcome the period of transient without impact to its output voltage, but higher voltage than specified can be dangerous due to the effects of radiation.

Protection circuits

Protection circuits should cover overvoltage, undervoltage and overcurrent. All protection values must be programmable, indicated in front panel of supply and via remote control. The reaction of power supply should be off state but each of three types of protection must be possible to enable/disable.

The protection against abrupt short circuit of each of 1700W supply output will be performed by quick–acting fuse (3 fuses / crate). Testing protocol of each 1700W supply must involve statement of burnout of this fuse at abrupt short-circuit test of this supply. Blow-up of the fuse must be also indicated on front panel.

MECHANICAL PARAMETERS

Requirement is based on power density estimations. Three output supply should fit to the standard, rack mounted 19" box, 4U high, with full depth (~65 cm). Top and bottom cover should be perforated to enable vertical airflow through the box. All other walls should minimise the leak of air from box. All main control parts, as they are switches, displays etc. must be accessible on front panel. On the rear panel should be only connectors for input and output power, fuses etc.

DEPLOYMENT

All bulk supplies will be placed in USA15 cavern, TILECAL region in 3 standard ATLAS racks 52U high. In Appendix1 is visible deployment of crates over rack. 9 crates will equip 2 racks as it is on the picture. It means 27 outputs/rack. Third rack will consist of only 4 crates and only 10 outputs from 12 will be used. Power will come from top of rack bus bars. Output will go down to cable trays placed under floor.

COOLING

Deployment of airspeed over crate width is not homogenous and to have the best cooling means to put cooled parts close to the center of box. See [1]. As an example is added Appendix 1 with preliminary design of crate deployment inside standard ATLAS rack. On top of each rack is turbine & rack control unit 4U high, which sucks the air from bottom to both sides of rack. Sides of rack are working as a tubes and partially also as a heat exchangers and they lead the air down to air deflector in the bottom part of rack. Air deflector is 2U high and closes the circle of air inside rack. So the air flows in closed loop through the cooled electronic crates, then via turbine and through the sides down back to deflector.

To get the heat off the rack few heat exchangers can be mounted. Because of resistance against air, the heat exchanger is coupled with fan tray to compensate it. According to [1] is possible to cool out 1.5kW simply by 1U heat exchanger. Then in case of supposed efficiency and input power the power dissipation from 3 bulk supply crates should be ~1.5kW so then for each 3 crates is one heat exchanger & one fan tray. Filled height is then 48U. 4U are empty.

After prototype delivery will be done some thermal measurements to be sure that set-up described above is sufficient. In case not the 4U space is possible to use by 2U heat exchangers instead of 1U and then increase the cooling power.

According to [1] the temperature inside rack had not been over 40 degree of Celsius in the worst case.

STEERING

Minimum functionality is the on/off input power (manually), on/off converter electronically. All parameters of power supply should be measured and displayed. This means especially all output voltages and currents, output power & input power. Should be indicated also status of whole power supply and each of its outputs in both states on and off and also failure states if exist.

Interlock circuit must be hardwired to have straight impact to the output voltage. Interlock input should work like isolated current loop 10mA. In case of current drop the power supply is going to off state. After revival of interlock current the supply must stay in off state until start command arrives. Interlock must have enable/disable switch. Each output channel of the supply must be equipped by separate interlock circuit to be able to trip off only affected channel without impact to others. Enable/disable switch should be placed on the front panel of each channel unit and its status indicated.

REMOTE CONTROL

Power supply must be equipped by remote control. All functions should cover all local control functions plus some additional functions. There is recommended to use some ATLAS standard protocol for communication with power supply. ATLAS DCS standard is CANbus with protocol CANOpen.

Best solution would be to use ready-made embeddable module for communication. For CANbus / CANOpen protocol exists module called ELMB [4] developed by ATLAS DCS group. This module is already equipped by ADC and digital I/O and uses CANOpen protocol, so it is simply embeddable to any application including software. Its connection to SCADA systems already exists.

Next possible solution could be any other kind of embeddable module like single-board PC with ETHERNET & TCP/IP or industry standard serial line (RS422). All 64 power supplies should be connected to one network and controlled via ATLAS DCS system [5].

RECOMMENDED CONNECTORS

To connect 3 phase input is required pigtailed cable coming from rear panel of supply to the standard European 5 wire 3 phase plug for 16A. Length of the cable should be 2.5m.

Remote control connectors are dependent on the remote control system are under specification of network or bus which will be used.

Interlock connectors are the LEMO type and for the prototype will be delivered by CERN. All interlock connectors should be placed on the rear of the box close to each channel.

INFORMATION SOURCES

[1] G.Thomas, LHC Rack Cooling Measurements

[2] Personal consultations with Paul Maley EP/ESS group

[3] Consultation with Joaquin Inigo-Golfin

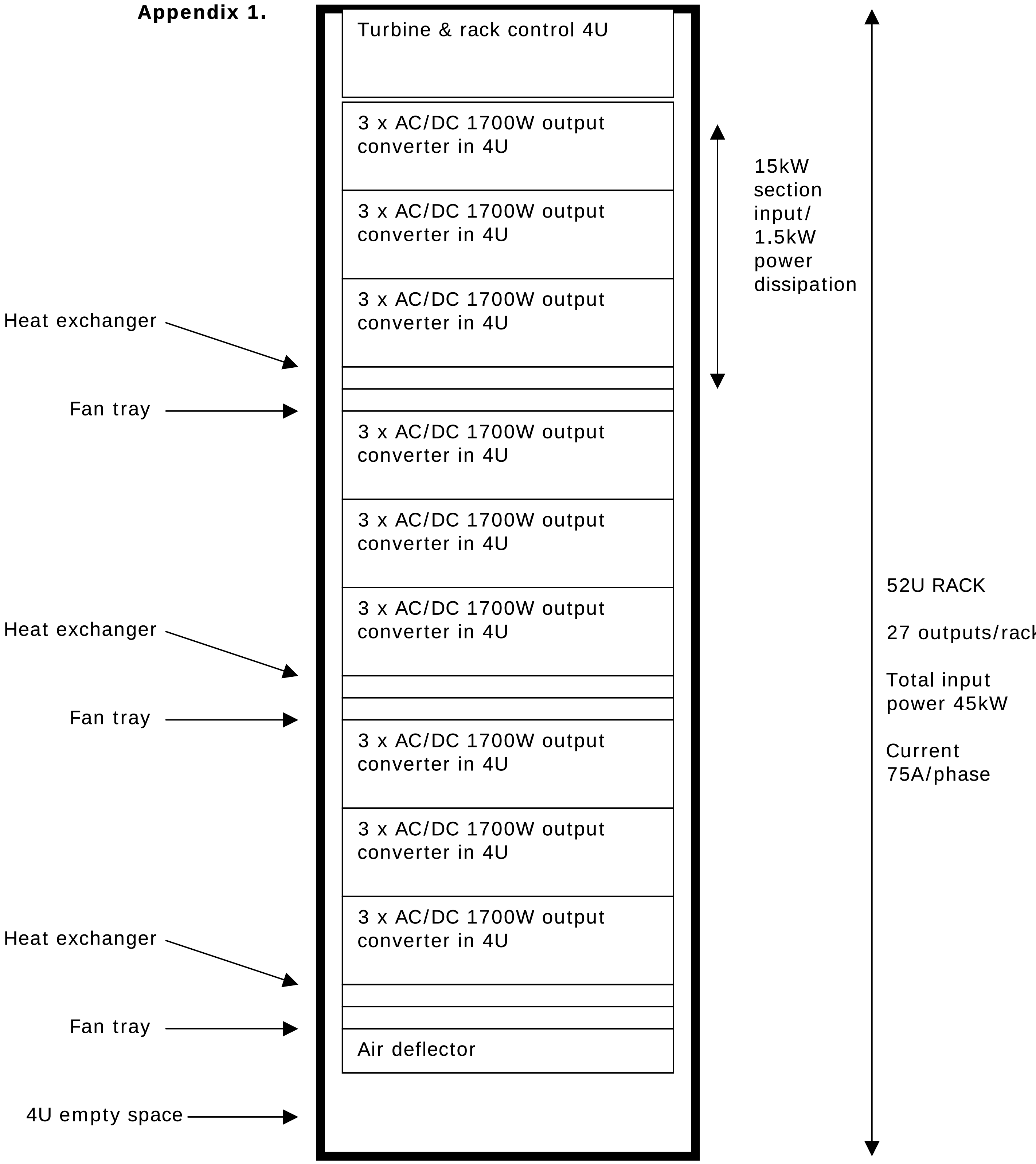
[4] http://elmb.web.cern.ch/ELMB/elmb.html

[5] http://atlas.web.cern.ch/Atlas/GROUPS/DAQTRIG/DCS/dcshome.html

[6] Low voltage power supply for TILECAL – WWW pages

http://atlas.web.cern.ch/Atlas/SUB_DETECTORS/TILE/production/electronics/LV_power_supply_for_TILECAL/Power_supply_main_page.html

Appendix 1.



Turbine & rack control 4U
3 x AC/DC 1700W output converter in 4U
3 x AC/DC 1700W output converter in 4U
3 x AC/DC 1700W output converter in 4U
Heat exchanger
Fan tray
3 x AC/DC 1700W output converter in 4U
3 x AC/DC 1700W output converter in 4U
3 x AC/DC 1700W output converter in 4U
Heat exchanger
Fan tray
3 x AC/DC 1700W output converter in 4U
3 x AC/DC 1700W output converter in 4U
3 x AC/DC 1700W output converter in 4U
Heat exchanger
Fan tray
Air deflector
4U empty space
15kW section input/ 1.5kW power dissipation
52U RACK
27 outputs/rack
Total input power 45kW
Current 75A/phase