Technical review of DQLPUR (Power Block) power supplies for iQPS.

Date: November 30th, 2012

Reviewers:
Markus Brugger (EN-STI), Betty Magnin (TE-MPE), Yves Thurel (TE-ECP)

Present:
Andrea Apollonio; Zinur Charifoulline; Giorgio D'Angelo; Knud Dahlerup-Petersen; Reiner Denz; Fabio Formenti; Vincent Froidbise; Spyridon Georgakakis; Joaquim Mourao; Stephen Pemberton; Bruno Puccio; Andrzej Siemko; Jens Steckert; Jean-Marc Wickham; Markus Zerlauth

Aim of the technical review.

This technical review aims at discussing the development of the DQPLUR (Power block) supplies for the initial QPS system. The system requirements, the technical details of the design and the test facility will be considered in order to validate the prototype. 2700 units will be produced for installation in LHC during LS1.

Meeting agenda (Indico).

Technical review of the initial QPS (iQPS) Power Block Supplies

Friday, November 30, 2012 from **09:00** to **13:00** (Europe/Zurich)
at **CERN (112-R-034)**

Description Reviewers:

Yves Thurel, Betty Magnin and Markus Brugger

Participants Markus Brugger; Zinur Charifoulline; Giorgio D'Angelo; Knud Dahlerup-Petersen; Reiner Denz; Arend Dinius; Fabio Formenti; Vincent Froidbise; Spyridon Georgakakis; Betty Magnin; Christophe Martin; Joaquim Mourao; Stephen Pemberton; Rudiger Schmidt; Andrzej Siemko; Jens Steckert; Yves Thurel; Jean-Marc Wickham; Markus Zerlauth

Friday, November 30, 2012

09:00 - 09:20 Project overview and plans *20'*
Speaker: Knud Dahlerup-Petersen (CERN)
Material: Slides

09:20 - 09:40 Design of the power box *20'*
Speaker: Joaquim Mourao (CERN)
Material: Slides

09:40 - 10:00 Design of the test system *20'*
Speaker: Mr. Zinur Charifoulline (CERN)
Material: Slides

10:00 - 10:20 Preliminary prototype test results *20'*
Speaker: Stephen Pemberton (CERN)
Material: Slides

10:20 - 10:40 Coffee break

10:40 - 11:00 R2E issues *20'*
Speaker: Dr. Reiner Denz (CERN)
Material: Slides

11:00 - 12:00 A.O.B. *1h0'*

Summary of the presentations.

The powering scheme of the initial QPS (iQPS) system is based on 1232 not redundant commercial power supplies (Syko – limitedly radiation tolerant), as it was originally conceived.

Three are the main reasons for which this system needs to be upgraded:

1) Some Syko supplies have showed a high fast transient current that activates the F3 circuit breakers and the reason of this was not identified
2) The new quench heater supervision electronics for the main dipoles imposes power requirements not compatible with the present supplies
3) The re-design of the DQLPU crates and Crawford boxes gives the opportunity to introduce new power supplies with safer radiation tolerance performance and full redundant power scheme (up to the UPSs).

The recovered Syko supplies will be reused to provide full power redundancy for the QD and QF protection electronics including spares. The corresponding QD/QF electronics crates already foresee the installation of duplicated power supplies operating in parallel (more details from Knud's presentation).

The new power supply design is based on linear technology. It provides 6 regulated outputs with current protection (+5.6 V grounded, +/- 15 V grounded, +5.6 V floating, +/-15 V floating). The insulation between floating channels is better than 1.9 kV. All outputs provide minimum 100 msec voltage maintain following a mains power cut. 2700 DQLPUR will have to be produced (more details from Joaquim's presentation).

The previous test bench for production quality assurance of the nQPS Power Packs can be modified and re-used for the iQPS Power Blocks. The hardware (both, Burn in and Functional testers) and the software (Labview) require design upgrade. With the available three Functional testers and nine Burn in testers (36 channels), up to six Power Block can be qualified at the same time (more details from Zinur's presentation).

The first two prototype units have been tested in the laboratory for thermal performance, output voltage decay time and ripple. These initial tests showed that the requirements were achieved. In particular with the revised correct total power consumption (40 W max) and improved cooling for the most critical component, the maximum recorded temperature was kept below 60^{o}C (more details from Stephen's presentation).

No radiation tolerance problems are expected from the Power Blocks. The key components are the same as those used in Power Packs and the unit's location in the tunnel is similar. Satisfactory radiation tests were conducted for the Power Pack electronics components and nearly 900 units worked in the LHC tunnel without reporting radiation induced problems. Further radiation tests are regarded as not necessary (more details from Reiner's presentation).

Main comments and recommendations from the reviewers.

1) The requirements on the output power to be delivered, its possible future increase and the design margins are not fully clarified. Although the actual limits seem correctly calculated, a block diagram explaining present and future operation conditions is not provided.
   <u>Recommendation</u>: *review the power needs in all possible operation conditions; provide a diagram of the different power scenarios and redundant cases; define appropriate margins accordingly.*

2) The valid input voltage range for a correct operation of the Power Blocks is not declared. UPS fluctuations and losses of the power line should be included.
   <u>Recommendation</u>: *obtain fluctuation and losses from EN-EL and check the design versus worst case; remake laboratory prototype power tests for worst case (e.g. output voltage, thermal tests); validate the voltage across the super-capacitors in all power conditions and in comparison with necessary stored energy and maximum allowed voltage for a given lifetime.*

3) The level of harmonics from the UPS can be high (some Vrms up to 8 kHz). No output noise voltage performance is given, for both, common and differential modes. This is particularly important for the floating outputs.
   <u>Recommendation</u>: *test the rejection performance of the system when injecting input noise in the range of 100 Hz to 100 kHz.*

4) The insulated outputs are completely floating when not loaded. The supplied voltages are low, but this will not prevent an electrical shock from common mode voltage.
   <u>Recommendation</u>: *guarantee the electrical safety of the floating outputs.*

5) The specification of the 5.6 V output is not clear. As this voltage can be trimmed from 5.0 V to 5.6 V, depending on the minimum voltage required at the load end, it is not known if the output power will be shared 50-50 between the two redundant supplies connected in parallel. The operation margin of the supplies depends from the correct power sharing.
   <u>Recommendation</u>: *clarify and set the correct 5.6 V output voltage level; check the requirements on cable resistance to allow compensation of the differences on the output voltages of the two parallel supplies; provide the way to adjust the output voltage once the Power Block units is installed into its rack.*

6) On the second prototype one 15 V floating output showed some instabilities.
   <u>Recommendations</u>: *identify clearly the reason of this instability and correct the cause.*

7) It was not given any estimation on inrush currents, neither a possible impact on the UPS. No scheme of power up sequence is planned.
   <u>Recommendation</u>: *measure the inrush current by cycling many times the start of the power supply and catching the worst case; study the scenario of powering up all the iQPS crates in the LHC arc, if necessary delaying the power ON by groups of them.*

8) The new linear power supplies are less efficient than the previous (Syko) switching supplies.

Recommendation: check with EN-EL that the UPS can safely provide to all customers the additional power required.

9) No fuse is provided for the internal unit safe (i.e. not for load protection).
Recommendation: install a fuse preventing major consequences in case of internal shorts and implementing selectivity close to the load.

10) A strategy for optimal unit's availability in function of component's lifetime and preventive maintenance is not defined.
Recommendation: define the goal; identify and characterize through datasheet or dedicated tests the critical components; specify a maintenance plan for 10-15 years' time and design the unit for easy maintenance; in particular for super-capacitors, their lifetime in function of operation temperature and TID should be evaluated; the solution of placing the super-capacitors in a pluggable box could be envisaged .

11) 1.9 kV minimum insulation voltage was specified between floating channels, but ELQA performs tests up to 2.1 kV. The device is tested for production QA at 2.2 kV.
Recommendation: the minimal QA test voltage should be 2.5 kV, 3 kV is the optimal target; insulation tests have to be well defined (e.g. AC, DC, threshold on max leakage current for reject, maximum relative humidity conditions, storage conditions); particular attention should be given to the HV performance of the connectors (organize dedicated acceptance tests if parameter not given by datasheet) and the heat sink insulation, especially if degraded by radiation doses; when units are installed in the LHC tunnel, in case of an insulation fault a method for an easy identification of the faulty device(s) has to be defined.

12) The radiation tolerance performance of the series regulator (LT1084) seems acceptable for the application, but samples and tests are old.
Recommendation: 6x2700 of these regulators will be used; it is worth to perform a new radiation test to characterize the whole batch to be purchased (single order managed by design team).

13) Further radiation tests for prototype.
Recommendation: although problems from radiation environment are unlike to happen, in view of the high number of units to produce, the first operational prototype could be tested for TID and maximum stress (e.g. check output voltage stability, max dose before breakdown); these tests can be outsourced.

14) Production testers, test procedures and software will be adapted from the past case of the nQPS Power Packs.
Recommendation: organization of the production test is a sizable part of the project; hardware and software to be upgraded, procedures, logistics and responsible people have to be better specified; the construction and validation of a test bench should be performed in parallel with the development of the Power Block unit to meet the project timescale.

15) Market survey has been launched (closing date December 4th). The tender is planned for December 17th (closing date January 28th).
Recommendation: the schedule is very tight and CERN will have to take a maximum of responsibility in defining all component orders and production details; critical

components consist at least of transformers, super-capacitors and series regulators and all of them shall be secured very soon as deliveries are long; the PCB is not complex, but due to the project schedule it should be manufactured by a supplier with known reputation for quality; the assembly manufacturer shall be precisely instructed (documentation) about bill of material, procedures and tests (testers delivered by CERN).

16) 10% of spare units are planned.
<u>*Recommendation*</u>*: this number, defined from the past experience of the Power Packs, should be verified versus the desired MTBF in the most realistic scenario for operation.*

17) Syko supplies will be re-used for QF/QD electronics crates
<u>*Recommendation*</u>*: for the global reliability of the SC magnet protection system, the Syko supplies should be qualified for confirming/excluding the SEE sensitivity and to study radiation induced ageing problems; in particular, the reason of the past failures should be better investigated.*

Conclusions.

The reviewers congratulate the design team for the advanced status of the Power Block project and acknowledge the tight time schedule for final installation in LHC. It is also important to note that this review has not discussed any topics for production readiness and planning.

The technical design is on good shape and the main recommendations concern the clear definition and update of some critical system parameter limits (margins on power, input voltage range, output noise rejection, HV insulation limits, 5.6 V output voltage definition, inrush currents, component's lifetime, device safe protection).

The design is derived from a previous similar unit and uses the same commercial components. Therefore, although the radiation tolerance should not represent a major concern, in view of a very large order of these components, it is recommended to perform new radiation qualification tests of the regulators and purchase the full amount within the same fabrication batch.

A danger is seen in the test bench upgrade and the manpower allocated to it. Responsibilities seem not yet well identified and the availability of a functional test bench is on the critical path for the mass production.

Similarly, the finalization of the technical documentation (electrical and mechanical) and the bill of material of some critical components to order are urgent.

The reviewers do not see technical showstoppers and recommend the continuation of the project.