OTHER SYSTEMS – WHAT NEEDS TO BE DONE? REPAIR AND REINSTALLATION OF OTHER SYSTEMS

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Abstract

After the incident occurred on the 19th September all equipment and systems (such as QPS racks, PC, BLM, Cryo instrumentation control etc.) located in the tunnel, especially in the affected area, were removed in order to allow an easier damage inspection. After a change or repair all these equipments will be re-installed in the tunnel and re-tested.

In this paper the needs of every system and the activities to be done in order to avoid interference, facilitate and optimize the process of re-commissioning of Sector 34 are presented.

THE INCIDENT OF 19TH SEPT. 2008

On 19th September 2008, during powering tests of the main dipole circuit in Sector 3-4 of the LHC, a fault occurred in the electrical bus connection in the region between a dipole and a quadrupole, resulting in mechanical damage and release of helium from the magnet cold mass into the tunnel.

The analysis of the accident showed that all the major systems (magnets, vacuum, cryo, electrical distribution) were severely damaged: the management decided to lunch an immediate repair campaign of the sector and to anticipate the shutdown period of the accelerator complex.

GENERAL ACTIVITIES

After the incident of the 19th September, many activities to strengthen the safety of LHC were undertaken (i.e. the installation of a new layer of the quench detection system to detect the faulty splices and symmetric quenches, the installation of new safety valves for the He release). Besides, many interventions were planned for the shutdown in order to improve the functionalities of some systems seen during the 2008 commissioning phase.

This section briefly illustrates the different activities ongoing in S3-4 as well as in some other sectors.

The Quench Detection System

The analysis of the 19th September incident clearly showed that the event was caused by the opening of a faulty inter-magnets joint, with the consequence that an arc was created between the bus-bar and the He pipe which finally melted [1]. In order to detect these types of quenches a new layer on the existing Quench Detection System able to detect the presence of a bad connection was studied and then being installed.

The new system has also a functionality to detect the so called “symmetric quench” experienced during the training campaign of sector 56 which occurs when the two apertures of a dipole magnet experience a quench at the same moment. The QPS works with the voltage across the one aperture, in order to get rid of the inductive part the two aperture signals are compensated each others in order to see resistive voltage spikes once a quench develops in one of the two aperture. If the quench develops in the two apertures at the same time the two voltage signals remain compensated and the detection of the quench fails resulting in a risk of damage for the circuit. All functionalities of the new system as well as the details of the installation can be found in [2].

Valves DN 200 and DN90

The melting of the He pipe due to the arc caused by a splice opening allows the He going into the insulation vacuum where it expands. DN90 valves are installed on top of the SSS to release the He into the tunnel in case of vacuum contamination avoiding the pressure to increase excessively. Those valves are designed to cope with a maximum flow rate of 2Kg/s which was not sufficient to evacuate all the helium during the incident of the 19th September and to face the high overpressure.

New valves (DN200) to release the He more quickly and avoid damage to the nearby magnets will be installed on the top of each dipole cryostat and a new releasing mechanism will be put in place on the existing DN90 on each SSS.

More details on this activity can be found in [3].

The Jacks

As the He release valves were not designed to cope with the pressure reached during the incident the overpressure broke two vacuum barriers moving several cryostats. The support of the SSS couldn’t keep the magnet in place and few were found severely damaged.

A new design of the jacks was proposed and approved in order to stand the stresses that could develop in a 19th Sept. incident type; the details can be found in [4].

Level sensor of the Stand Alone Magnets

During 2008 commissioning it was discovered that the LHe level sensors of the stand-alone magnets are not fully reliable because of a design problem. Their improvement by installation of a flexible capillary with a bigger diameter and without low point is ongoing to increase the reliability. For details refer to [5].

Direct current Feed Box

Some activities had been planned to take place during the shutdown in order to increase both safety and functionality of the DFB, such as:

- Installation of electrical protections in front of current leads;
- Improvement of the configuration of the safety valves discharge outlet;
- Installation of additional pressure switches for the dry air system;
- Installation of mechanical protection for DFBM & DFBA links.

The details of these activities are in [6].

Collimators

Also some improvement and completion of collimators installation where planned during the shutdown:

- Full phase 1 system would be installed for 2009, removing limits for β*, luminosity, cleaning efficiency, protection and risks for collimator lifetime (early series production);
- Consolidation ring skew/vertical inox cages;
- Consolidation ring horizontal inox cages;
- Consolidation inox cages;

The details of these activities are in [6].

SPECIFIC ACTIVITIES

Besides all activities described on the previous section which are taking places in the whole LHC, many activities for consolidation and repairs of sector 34 are also ongoing. All these intervention can be divided into the ones due to the incident related and the maintenance and repair ones.

Incident related activities: 60A PC

Located under the magnets there are many racks, which were exposed to condensation, dust and He during the incident. Most of them were removed after the 19th September to be analyzed and repair.

Out of all 60A converters that have been removed and analyzed, 4 (located under cell 28R3) showed traces of oxidation (their DC connectors on DC cable side have to be changed) and 3 converters have required repairs:

- RCBH30.R3B2 (dead capacitor likely due to cold);
- RCBH24.R3B2 and RCBV24.R3B1 (overvoltage through current lead voltage taps);

The others 87 converters have been tested and they are fully operational. These systems will be re-commissioned during the powering test.

Incident related activities: cryo instrumentation

All the racks containing cryo-instrumentation electronics have been analyzed and only one card was found blown out most likely because of a piece of MLI creating an internal short circuit. The re-commissioning of this system consists in a visual inspection during the interconnection phase followed by a test during which a check of the coherency between the software signal and the hardware one is performed.

Incident related activities: QPS racks

All the Quench Detectors were also removed from the tunnel and brought in a laboratory where the ones coming from the damaged area will be analyzed and the others have just been cleaned.

Only the Quench Heater Power Supply located in the D-area were removed and just some of them analyzed; some have seen a dielectric breakdown at the level of the input diode bridge for charging of the capacitor most likely due to condensation inside the QHPS even if no clear explanation has been found so far. The repair can be easily performed and based on the situation found during the analysis of the other already removed a decision will be taken whether to remove them all or not. Just before the powering test the individual system test, consisting of charging and firing of the heaters will be done.

Incident related activities: vacuum and beam instrumentation

The vacuum equipment were removed and tested and no failure was found.

As well as the magnets, also the Beam Loss Monitors and the Beam Position Monitor have been removed in the whole sector and should be reinstalled and tested.

Incident related activities: Power Converters

The TE/EPC group requested to perform a 24h run of all the Power Converters belonging to sector 34 in order to check their performance after they have been overcharged during the incident. This activity includes all power converters of circuits located on the DFBAG, DFBAF and DFBL as well as the 120A converters that are connected directly to the magnets. This activity implies the set up of the short circuits at the level of the cables, a 24h run and removal of the short circuits (to be pointed out that the short circuit test in the UJ33 was performed at operational current profile because that is considered a sensitive area in term of heat load).

Maintenance and repairs: Undulator

The tests performed during the hardware commissioning of the undulator located in sector 34 (LU.L4) revealed that the internal resistor is broken (probably due to transport): the change of this magnets has been proposed but not yet decided; however the undulator is the only instrument that allow a precise measurement of the emittance at low beam energy.

Maintenance and repairs: Synchrotron Light Telescope

Some activities should be done also on the Synchrotron Light Telescope such as pulling of a control cable, upgrade of the alignment control engine of the optic system, change and regulation of the optic bench. The feasibility of the last activity is, however, under approval, because it’s not mandatory for operating the LHC at 5TeV and could have an impact on the LHC schedule.

Maintenance and repairs: DFBLC-DSLC

During powering tests of sector 34 it was discovered that all circuits located on the right module of the DFBLC showed a high resistance when powered at more than 100A. After investigation the problem was found on the top of the flexible part of the cryo-link (DSLC). The external flexible moved down and touches the superconducting cables generating a heat sink. As a consequence the temperature of the superconducting cables increased and an ohmic resistance appeared in the circuits. Anchoring the flexible part of the DSLC link in order to avoid the displacement that was responsible for the heat dissipation has identified as the problem solution being implemented.

Maintenance and repairs: warm magnets in IP3

The commissioning of the two warm circuits RQT4.R3 and RQT5.R3 showed the impossibility to keep the nominal current due to the increase of T of DC cables and magnets. This effect produces a significant increasing of the resistance of the circuits with the consequence that the power converters are no longer able to provide the nominal current. The solution proposed is to pull additional DC cables from the power converters to the magnets in order to reduce the resistance of the circuits and limit the DC cables temperature. Even if this intervention is not mandatory for operating the LHC at 5TeV it’s already ongoing. All details on this problem and its solution can be found in [7]. In order to re-commission these circuits the following steps will be carried out:

- Electrical quality assurance to verify the integrity of the circuits;
- Polarity check to confirm the cabling has been done correctly;
- 24h heat run to validate the electrical circuits (ventilation and equipments have been already validated in the previous campaign).

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