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Report

LHC Long Shutdown: A Parenthesis for a Challenge

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Abstract

After three fruitful years of operation, the LHC will enter a long shutdown. Major works will be implemented to allow running safely at seven TeV/beam. The LHC superconducting circuits will be consolidated; mitigation measures will be carried out to reduce the single event effects occurrence in the frame of the Radiation To Electronics mitigation project (R2E); all the equipment will be fully maintained. In parallel, numerous consolidation and upgrade activities will be performed all around the 27 km ring. The schedule has been optimized in order to reduce the length of the shutdown (LS1) to 22 months (including hardware commissioning). The organization of the works is therefore essential to ensure a safe and reliable plan. This paper introduces the various activities to be performed and presents the schedule and the preparation process, including the operational safety aspects.

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INTRODUCTION

The LHC reached 77% of nominal luminosity at half energy, enabling essential discoveries. After three years of impressive operation, the Long Shutdown number 1 (LS1) will allow the complete maintenance of all equipment, as well as the necessary consolidation and upgrade activities in order to ensure a reliable and safe operation of the LHC at nominal performance from 2015.

THE LONG SHUTDOWN ROADMAP

In the course of LS1, which will last around two years, the following sequence of activities will be performed in each of the eight sectors of the machine:

- Preparation: At nominal cryogenic conditions, each superconducting circuit, except the mains circuits, will be tested at seven TeV equivalent current [1]. Electrical Quality Assurance (ELQA) tests [2] will be performed at 1.9 K, as well as at room temperature. These tests will allow to better localize existing electrical faults in order to be able to repair or consolidate these circuits if necessary. Then, each sector will be warmed up and vacuum leak tested (at cold, and at warm), in order to check both the insulation and beam vacuums.
- LS1 core activities: maintenance, consolidation and upgrade activities;
- Preparing for cool-down including pressure tests, electrical quality assurance tests (ELQA), flushing, etc.;
- Validation: Once all the activities related to one sector are finished, all the circuits will be qualified at warm (ELQA tests) [2]. Then the sectors will be cooled down, power tested in order to qualify the machine for operation at nominal energy.

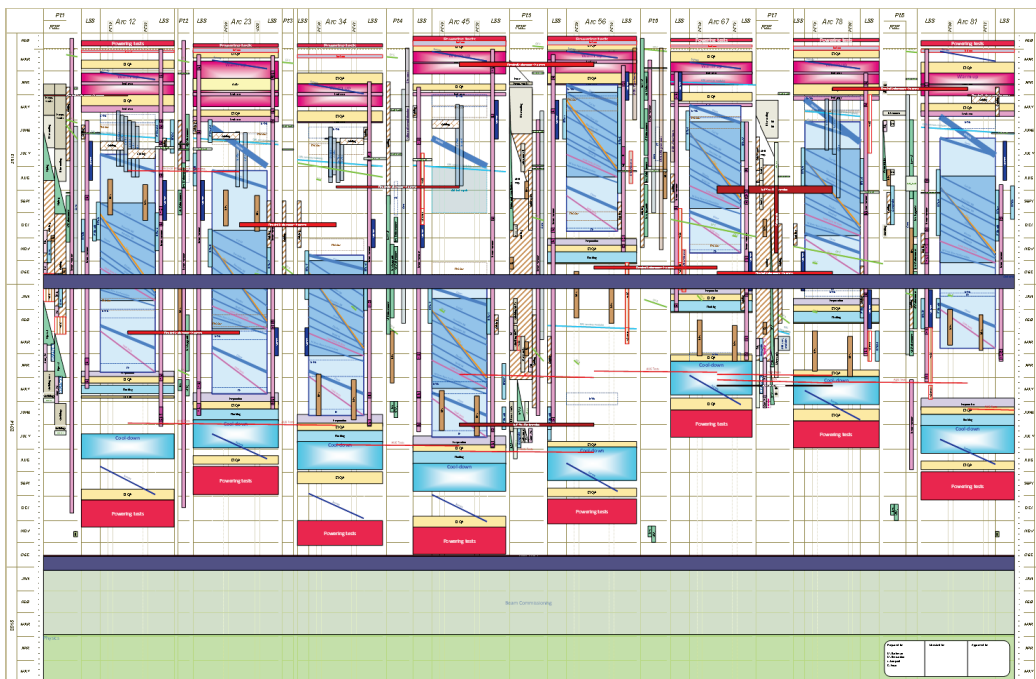


Figure 1: Long Shutdown 1 schedule in the LHC machine (EDMS: 1274997).

MAIN CONSOLIDATIONS AND MAINTENANCE

The focus of the works, which will be carried out, is on the consolidation of the Superconducting Circuits, the Radiation to Electronics (R2E) Mitigation Measures, and the maintenance. In parallel to the LHC shutdown, it is important to remember that the LS1 also includes major consolidation, upgrade and maintenance activities on the injector complex and on the general infrastructure supporting the accelerator complex.

Superconducting Magnets and Circuits Consolidation (SMACC)

Following the September 2008 incident, a complete analysis has been performed, and the corrective measures were reviewed by international expert panels. The main objectives are:

- The installation of shunts on the 13 kA busbar splices. The solution, which will be implemented, has been successfully tested in the workshop in similar conditions during 2012. The teams working on the consolidation will start at Point 5, going clockwise. The schedule is based on the production rate of the repair of 53 interconnection per week, namely the installation of a shunt every 3 minutes. The consolidation of the main splices will last 14 months;
- The consolidation of the DFBA (Distribution Feed Boxes of the Arcs) the splices in the superconducting circuits to the same standard as the arc;
- The replacement of 19 superconducting magnets showing a high inner splice resistance or a weakness in the quench heater circuit, or having reversed beam screens, and for beam optics improvement;
- The consolidation of the connection cryostats and of the Plug-In Modules; and
- The installation of the safety pressure relief devices on the cryostats of the sectors which were not warmed up since 2008.

The SMACC project involves more than 200 persons.

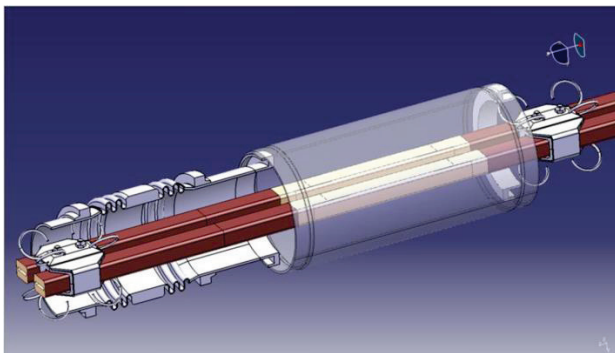


Figure 2: Consolidation of the dipole splices.

Radiation to Electronics (R2E) Mitigation Measures

The level of the flux of hadrons with energy in the multi MeV range expected from the collimation system at Point 7 and from the collisions at the interaction Points 1, 5 and 8 will induce Single Event Errors (SEEs) [3] of the standard electronics present in the equipment located around these Points. Such events would perturb LHC operation.

The foreseen improvements to mitigate the effects of radiation to electronics were studied in detail. This will allow the beam dumps caused by SEEs to be reduced from 600 to 20.

Fifteen groups will be involved in the relocation of 90 racks, power converters, electrical equipment, safety control units located in Points 1, 5, 7 and 8. The existing concrete shielding of Points 1 and 5 will be replaced by cast iron. Additional shielding will be installed at Point 8. Major civil engineering works will be carried out at Point 5 and Point 7 (ducts, removal of walls).

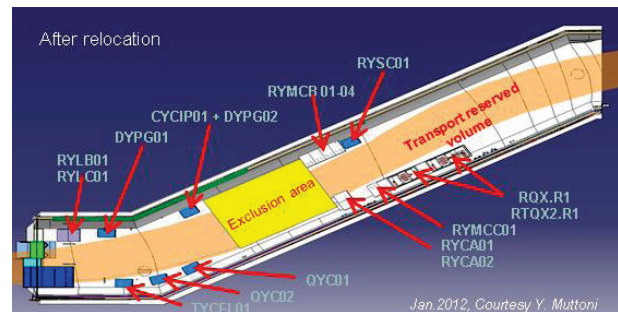


Figure 3: Equipment after relocation at point 1.

Maintenance

After more than 3 years of operation, a full maintenance programme of the various systems is needed. The maintenance of a cryogenic plant will last 18 weeks, mainly driven by the maintenance of the compressor stations. In shadow of the cryogenic maintenance, the cooling towers will be completely cleaned, and their electrical and mechanical maintenance fully carried out. A new electrical substation will be built in order to increase the reliability, and resize the system for the future needs of the accelerator complex. The programme also includes a lot of important maintenance activities that were delayed to reduce the time dedicated to technical stops and thus to increase the time dedicated to operation.

General Infrastructure consolidation and Upgrade

The general infrastructure of the CERN accelerator complex is aging and therefore requires consolidation and upgrade works in order to ensure a reliable operation of the LHC and its injectors:

- Subsequent to the analysis of the electrical network performed in 2007 [4], a number of projects were launched. These include the renovation of the SPS

electrical substations, the building of new substations (BE91 and 66kV), the replacement and upgrade of the LHC SILCON Uninterruptible Power Supply (UPS) systems in the LHC, the renovation of the protection systems of the complete 66 kV network supplying the LHC and the associated experiments.

- Moreover, the cooling and ventilation systems will undergo renovation or consolidation; the (strategic) raising pumps plant will be refurbished (because of the obsolescence of its control system); new cooling towers for LHC will be installed in parallel to the existing ones to allow the mandatory annual cleaning while keeping the cryogenics operational; the demineralized water production station for all CERN will be consolidated; the old PS ventilation system will be completely renewed.

In addition to the full maintenance and all these new, consolidation or upgrade projects, which can be launched only when the accelerators are not in operation, the same infrastructure groups will still have to ensure the operation of most of their installations. The workload of the concerned groups was carefully evaluated and projects were prioritized by the LS1 Project Leader to ensure the overall feasibility. Furthermore, additional resources, normally involved in the operation of the accelerators and the associated equipment, were temporarily transferred to the Engineering Department in order to help with these activities.

ORGANIZATION

All these activities, foreseen during LS1, are highly complicated to organize as they concern not only the LHC and its experiments, but also the injectors, the associated experiments as well as the general infrastructure systems. Because of all of this, preparation is crucial.

The Teams Involved

We have estimated that, at the peak of activities, around 800 persons would be working underground in the LHC. The two major consolidation projects will be performed working two shifts per day, while the associated logistics and the tests (X-rays and electrical) will be done overnight. This will minimise the length of the shutdown.

The workers are either contractors, or CERN staff (of which more than a third is dedicated to LS1), or collaborators from different countries.

During the installation, a central team (EN-MEF) will prepare, schedule, organize and follow up the long shutdown activities. This team will report to the LS1 Committee (LSC).

The Safety aspects

All the safety aspects have been carefully studied:

- The interventions are rigorously scheduled to minimize the co-activities. The description, logistics, safety hazards and associated compensatory

measures are recorded in Work Package Analysis Documents.

- While the machine is in operation or short technical stops, the two major risks are the Oxygen Deficiency and the Electrical Hazards. The first phase of the shutdown consists in removing or minimizing those risks, by emptying the magnets and the circuits of helium, and by locking out the main electrical circuits. All the workers have to follow safety courses in relation to the existing hazards [5].
- Evacuation simulations have been performed, according to the schedule, to check that, in case of alarm, the evacuation of all the workers will be possible and to prevent the access of more workers than can safely be handled.
- In addition, the authorization to start each activity is subject to the approval of the coordination team and the safety coordinators.

Access

In order to minimize the impact of the interventions on the restart, and considering the size of the accelerator complex, and its experiments, a strict control of the requests and a strong coordination are essential. In November 2011, the Intervention Management Planning & Activity Coordination Tool (IMPACT) was successfully implemented [6]. The tool integrates with the access system (ADAMS) so that participants of an intervention are automatically granted access to the right location at the right time.

SUMMARY

The parenthesis for a challenge will be challenging! This first long shutdown involves a high number of personnel, and includes essential activities to ensure a safe and reliable operation of the LHC at around nominal energy. All the activities were carefully studied and planned, and the necessary resources allocated.

The LS1 has just started and so far, all the activities are progressing according to the schedule.

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