PLANNING AND LOGISTICS ISSUES RAISED BY THE INDIVIDUAL SYSTEM TESTS DURING THE INSTALLATION OF THE LHC

E.Barbero-Soto[1,2], K.Foraz[1], F. Rodriguez-Mateos[1], S.Weisz[1]

[1]CERN, Geneva, Switzerland, [2]UPC, Barcelona, Spain.

Abstract

The running of individual system tests has to fit within tight constraints of the LHC installation planning and of CERN's accelerator activity in general. For instance, the short circuit tests of the power converters that are performed in-situ restrict the possibility to work in neighbouring areas; much in the same way, the cold tests of the cryogenic distribution line involve safety access restrictions that are not compatible with the transport and installation of cryo-magnets in the sector considered. Still, these individual system tests correspond to milestones that are required to insure that we can continue with the installation of machine elements. This paper reviews the conditions required to perform the individual system tests and describe how the general LHC installation planning is organised to allocate periods for these tests.

INTRODUCTION

The Large Hadron Collider (LHC) is installed in a circular tunnel 27km long, composed of 8 arc sections (8x2.9km, hosting superconducting magnets composing the continuous cryostat) and 8 long straight sections (8x0.5km, hosting superconducting magnets and room temperature components). The installation and commissioning of the machine involve a large variety of systems (i.e. power converters, quench protection, powering interlock, etc.) and each of them has to be tested individually in order to validate its proper functioning. Such tests can be quite complex, due to the large amount of components which are part of the systems and due to the installation and tests constraints. The Individual System Tests (IST) must be performed prior to the global hardware commissioning phase that includes electrical quality assurance at warm, cool down and powering tests. One of the challenges, when planning the installation of the LHC, is to schedule these IST in the shadow of the critical path so that they do not delay the completion date of the machine.

CRITICAL PATH OF THE LHC INSTALLATION PLANNING

The critical path of the LHC Installation and Hardware Commissioning is composed of [1]:

For the arcs and the cold part of the long straight sections:

- Installation and commissioning of the cryogenic line (QRL).
- Installation of all the components needed, including transport, alignment and interconnection of the continuous cryostat.
- Global pressure and leak test.
- Consolidation and final closure of the interconnections.
- Hardware Commissioning, including electrical qualification at warm, cool-down and powering tests

For the room temperature elements of the long straight sections:

- Installation of all the components (warm magnets, beam instrumentation, vacuum chambers, etc.) needed, including transport, alignment, and mechanical and electrical connexions.
- Bake-out and NEG activation of the vacuum sub-sectors.
- Hardware Commissioning, including electrical qualification at warm and powering tests.

INDIVIDUAL SYSTEM TESTS

The IST have to be prepared and scheduled in a given sequence and according to the master installation planning. To be properly tested, each system requires a set of conditions, which can be divided in four groups:

- General services: cooling, Ethernet, WiFi, electrical distribution systems, etc. The general services are commonly required for all the individual tests.
- Installation of the concerned system components.
- Other system tests & installations.
- Access and safety.

Excluding the general services systems, the systems to be tested prior to the hardware commissioning are:

Cryogenic Line

The cryogenic line is feeding the superconducting magnets with cold helium ranging from 4K to 75K. Each sector is validated after its installation by a pressure and leak test. During the test, the pressure in the lines can reach up to 27.5 bars. A procedure is in place with a view to limit access in the sector for the duration of the pressure test (typically 1 day).

Collimators System

The LHC collimation system will protect the accelerator against regular and unavoidable irregular beam loss. No special access restriction is required during the individual system test of the collimators. The collimators have to be aligned prior to the IST, and the corresponding vacuum sub-sectors has to be baked-out.

Powering Interlock System

The Powering Interlock System protects the power part of the machine. The tests have no direct influence on other installation activities but they have to be done before the start of the tests of the power converters. There is no access restriction during the IST [2]. The Powering Interlock Controllers (PIC) have to be installed, the PIC supervision system has to operational, the Quench Protection System and the power converters have to be installed prior to the IST.

Energy Extraction System

The Energy Extraction (EE) system extracts the energy of the circuits in order to protect superconducting magnets during a quench. Access restriction around the equipment is required during the IST and a procedure is in force [3]. The EE system is installed and connected to the power converters and to the cooling system prior to the IST.

The EE IST has to start 1.5 to 2 weeks before the short circuit tests and they continue during all these short circuit tests.

Beam Instrumentation

The Beam Instrumentation (BI) system provides beam parameters. The installation of beam loss monitors (BLMs) and beam positions monitors (BPMs) electronic racks, in the cold areas, are done during the closure of the machine due to mechanical constraints. The installation of the corresponding electronics in the warm regions is scheduled just after the bake out of the vacuum sub-sectors.

Part of the IST of this system employs a radiation source which implies access restriction in the whole sector.

Cryogenics Instrumentation

The Cryogenics Instrumentation (CI) tests have to be carried out after the magnet installation in a given sector. There is no access restriction during this activity but, due to the size of the equipment used to perform the tests, logistic (access and transport) has to be carefully planned.

Injection and Dump Systems

From the point of view of the installation, the requirements needed to perform the IST of the two systems are almost the same. It includes the components installations of each group: the kicker magnets (MKI or MKD), the associated pulse generators and trigger electronics. The bake-out of the MKI or MKD must be finished. No access restriction need to be applied during the tests [4].

Individual System Test of the Power Converters (Short Circuit Tests)

The Power Converters (PC) system feeds with power the magnets in the accelerator.

During the Short Circuit Tests (PC IST) [5], due to electrical hazards, access restrictions are in force in the underground areas where the power converters are installed. Moreover, during some periods of the tests, no activity can be done in the part of the tunnel where the cables being tested are hanging from the ceiling, waiting to be connected to the current cryo-feed boxes. This can interfere, for instance, with the interconnection activities and magnet transport. Fig. 1 shows the sequence of activities to perform the PC IST [6].

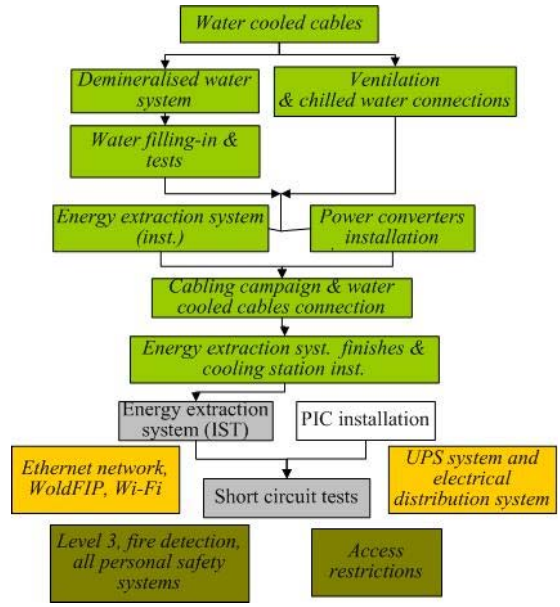

Figure 1: Requirements of the short circuit test: Green = installation activities, Grey =individual system tests, White = interference with other systems, Yellow = general services, Khaki =access and safety

INTERFERENCES AND DEPENDENCIES WITH OTHER ACTIVITIES

Several parameters have to be taken into account when scheduling each IST on the general installation planning: duration, interferences, dependencies and access restrictions. Moreover, limited resources assigned to the installation and IST implies the need of a rigorous scheduling and follow-up of all the activities (often referred as “levelling” in planning jargon).

We classified the interferences and dependencies of each IST with other activities into two groups according to the effect a change of the installation schedule would have on the test.

Dependencies with activities of the Critical Path

The first group of interferences and dependencies are those associated with installation activities on the critical path. In this case, the IST has to adapt its schedule and work conditions to the dates and conditions imposed by the activities on the critical path. This adaptation has to be as strict as possible or it will cause a general delay of the completion of the project.

The dependencies with installation activities in the arcs and the cold part of the long straight sections are summarised in Table 1. Those referring to activities concerning the warm elements of the long straight sections are listed in Table 2.

Table 1: Dependencies with installation activities on the critical path in the cold part of the LHC

	Installation of beam line	Cool Down	Power Tests
BI	during	before	before
CI	parallel	before	before
EE	parallel	before	before
PC SCT	parallel	before	before
PIC	parallel	before	before
QRL	before	before	before

Table 2: Dependencies with installation activities on the critical path in the warm part of the LHC

	Installation of beam line	NEG activation	Power Tests
BI	after	during	before
CI	during	before	before
Collimators	after	after	before
MKI&MKD	after	after	before
QRL	before	before	before

Dependencies between Systems

The second group contains the interferences and dependencies between IST themselves. It is important to identify such relations since quite often the results of an IST are necessary for the start and completion of other system tests. These relations are shown in Fig.2

CONCLUSIONS

The Individual System Tests are integrated in the LHC Installation schedule taking into account the different requirements and constrains described above. However, scheduling the installation and individual system test is definitely a dynamic process: the detailed installation and Individual System Test planning is reviewed regularly within the installation meetings and hardware commissioning meetings.

Finally, the reactivity in front of any delay or change can be done in an efficient and controlled way thanks to the identification and definition of all the parameters involved and inter-relations between the activities. Nevertheless all safety rules must be strictly enforced to avoid accident and there is no emergency that can justify any derogation.

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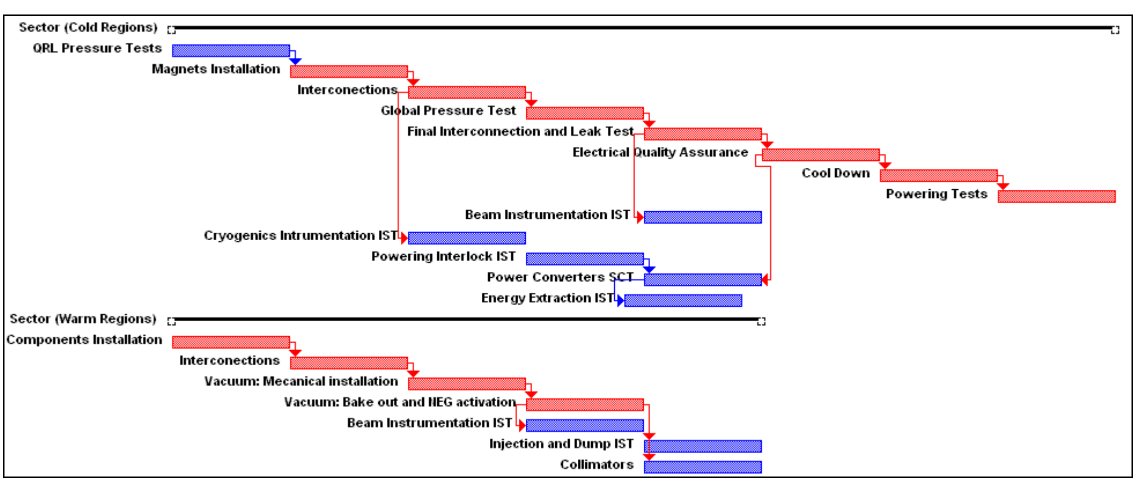

Figure 2: IST dependencies with the activities on the critical path and in between ISTs. Red bars correspond to installation activities and blue bars to IST (bar lengths do not represent the precise duration of the activities)