CONTROLS

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Abstract

The roadmap towards fully operational LHC controls is discussed. Controls for beam operation will be similar to other CERN accelerators. From the experience gained with the TI 8 tests, milestones such as the commissioning of LEIR, the LHC injection test and TI 2 commissioning, the controls for LHC will be realised with the same building blocks as used today. Hardware commissioning will provide a different challenge with a large scale use of industrial solutions for accelerator control. Long before the first injection into the LHC, controls for vacuum, cryogenics, quench protection, powering interlocks and power converters must be fully operational. Current plans for the installation and commissioning of the controls infrastructure are explained and the main aspects are highlighted. The generic controls facilities required for the commissioning of the hardware and for beam operation are discussed with emphasis on how the work is advancing in different domains such as post-mortem, logging, alarms, timing, and high level applications. The requirements, in particular for Hardware Commissioning, and how they translate into existing controls and technical specifications, are addressed. The presentation is based on the summary of an AB-CO meeting (CO-Day) that was held in December 2004.

INTRODUCTION

Considering the compressed LHC schedule, the concurrent requirements from LEIR, CNGS, the CERN Control Centre and other developments, prompt availability of the control system becomes even more critical.

A one day AB-CO workshop was organised in December 2004 with the following aims:

- to ensure that the controls systems are ready on time
- to establish the goals and milestones for 2005 and 2006
- to prepare for 2007 and 2008.

The workshop was intended to review progress, to expose problems, if any and to provide written documents for controls clients – presentations and conclusions from the workshop are available [1].

Major milestones for controls, as identified at the workshop, are shown in Fig.1. Such milestones are essential, since the approach of the Controls Group is a progressive deployment and evolution of solutions to satisfy successive accelerator projects across CERN.

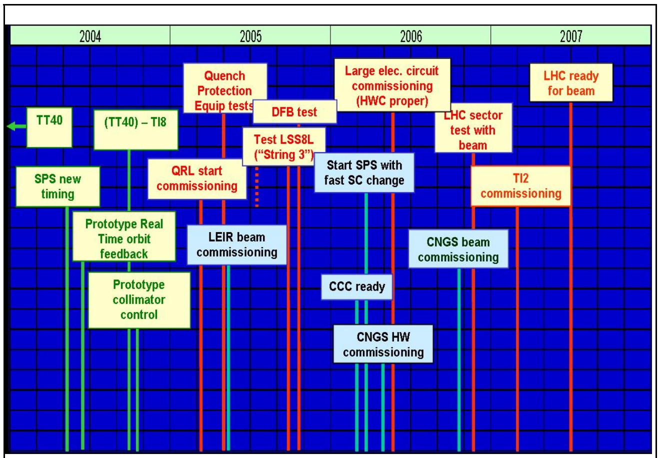

Fig. 1: Major milestones for controls

LHC CONTROLS HARDWARE

A substantial amount of hardware is being provided by the Controls Group:

- Front ends and Gateways: Computers including PLCs, some 300 VME based systems and over 150 rackable PC gateways will be installed.
- Communications infrastructure: Ethernet is provided by the IT department, but the Controls Group provide coordination and testing. The group is responsible for the real time WorldFIP fieldbus infrastructure which includes 200 km of cabling, around 40'000 passive and some 1'100 active elements. Coordination for the WorldFIP and Profibus fieldbuses is provided for the whole of CERN.
- Field Control Rooms: the group will install and support consoles, servers and large displays for the FCRs during Hardware Commissioning and provide some support for mobile consoles in the underground areas.
- Custom electronics: many developments are in hand for the timing system, the beam and powering interlocks and the system to generate and distribute the Safe LHC Parameters.
- Timing System distribution: this will be via long distance optical fibres and locally copper cables – the associated electronics is being developped.
- Central Timing: the CERN accelerator timing system that coordinates beams across CERN is being extended to the LHC. It is planned to install the VME central timing generator in the CCC (CERN Control Centre).
- The Remote Reboot Service for PC Gateways, PLCs and Field Interfaces includes about 30 Schneider PLCs for the reset of remote front end systems.

- Terminal Service: this will include around 20 networked terminal servers providing serial line access to systems for debugging and maintenance.

The controls hardware installation planning is being addressed, and the detailed planning for sectors 7-8 and 8-1 is being finalised in coordination with the TS department. An installation body is in place since end of January. This body will define detailed tasks and responsibilities for all sub-systems such as cables, front end hardware and software, system administration and diagnostic tools. Close follow-up linked to the planning will be organised.

SERVICES OFFERED BY CONTROLS

There are several general tools that have been developed:

- A complete software environment, Front End Software Architecture (FESA), provides a run time framework and development environment for front ends. The work is a collaboration between the Controls and BDI groups.
- The communication services between software running on many different systems are provided by the Controls Middleware (CMW) package.
- UNICOS developed at CERN is used as software framework for SCADA and PLC developments. (SCADA stands for Supervisory Controls and Data Acquisition).

A large fraction of the control room accelerator application programs is being developed by the LHC Software Applications (LSA) team, drawn from Controls and Operations groups working in close association with the equipment groups. The objective is to develop generic application software to be deployed across the CERN accelerators.

Key software services are planned to integrate data from across the LHC and associated systems. The LHC Logging service is operational, the LHC Alarm Service is being deployed and Post Mortem recording of critical systems is being prototyped with the LSA team. A generic system for recording transient data (OASIS) has also been tested.

Many of these products were already deployed during the TT40 / TI 8 extraction tests, during the SPS run, and during the running-in of the LHC cryogenic plant.

DEPLOYMENT

For operation of the LHC beams, controls for transfer lines, injection and extraction (beam dumping system), beam optics controls, beam instrumentation, RF, beam interlocks, collimation, real time orbit feedback and radiation monitors will be required.

The tests of the TT40 and TI 8 lines allowed to commission prototypes for some of these systems. Beam optics controls for TT40 and TI 8 was performed with applications using the generic LSA software infrastructure. LSA also supplied displays for beam instrumentation.

The beam interlock system using identical hardware as the systems for the LHC was also operational for the TT40 and TI 8 tests. The system is based on VME electronics. The FESA framework runs in the front ends and the supervision has been developed with a dedicated JAVA application.. The data were logged into the LHC logging system.

In preparation for LHC Collimation prototypes, both in the SPS and TT40 using stand-alone controls, gave valuable experience.

A small scale real time orbit feedback system for the SPS worked very well during 2004 and is considered as first promising step for LHC real time orbit control.

The vacuum systems of SPS, TI 8 and TT40 are already being controlled with the same industrial hardware and software that will be used in the LHC. Logging of the data via the logging system provided by the Controls Group is fully operational.

The interlock system for the normal conducting magnets in TI 8 and TT40 is operational. Controls are built from industrial PLCs and SCADA. A display and logging of the TI 8 tunnel and magnet temperatures has also been provided by the system. The resulting knowledge concerning ventilation of injection lines and LHC tunnel is important for the optimisation of the LHC ventilation.

The controls for the cryogenics system at the LHC are being deployed with the cryogenic plants. Plant control at point 8 is operational but cryogenic control in the ring is on the critical path.

DATA MANAGEMENT

The LHC is an extremely complex accelerator. This complexity is reflected as a challenging data management task where consistency is vital. There are several areas of data management for the LHC:

- LHC Layout including mechanical data and the DC powering configuration. From the data stored in the database the MAD optics is automatically derived.
- Physical equipment with a catalogue of equipment, including serial number, equipment parameters and manufacturing data.
- Controls configuration with the topology of the controls hardware and the controls software. The ABCAM (AB-CO asset management) portal is now being deployed to support the installation data teams, including the racks of electronics and the connecting cables. Work here is on the critical path.
- Operational data including settings, measurements, data from logging, alarms and from post mortem recording.

Naming of LHC entities and signals must be consistent across the project. Naming conventions have long been defined for the LHC and recently adopted for operational naming of parameters [2].

HARDWARE COMMISSIONING AND CONTROLS

For hardware commissioning [3], control of power converters, the quench protection system, the cryogenics system, the powering interlocks, the vacuum systems, uninterruptible power supplies (UPS), emergency stops (AUG), safety systems and general services is required.

Before starting the commissioning of the powering system in the LHC tunnel, a section of the QRL will be commissioned. This requires controls for vacuum and cryogenics to be operational together with the basic controls infrastructure and services.

For a type test of a current lead feed box in SM18 (DFBA) all main systems will be commissioning together. This includes tests with four electrical circuits and requires vacuum, cryogenics, power converters, quench protection and powering interlocks.

The commissioning of the magnet powering system in the LHC will start with LSS8L ("String 3") requiring all main systems, as well as UPS and AUG. Two powering sub sectors with 29 electrical circuits are concerned.

The more time consuming part will be the later commissioning of 26 powering sub sectors with 1585 electrical circuits.

The main objective of the commissioning is the safe powering of superconducting circuits to nominal current levels. The electrical circuits will be qualified and the information on the qualification will be captured. The magnets will operate for several hours at nominal field to demonstrate the reliably of the powering system. For controls the objective is the commission and validation of the controls system, everything that can be done without beam should be performed during hardware commissioning and sub-sequent machine checkout.

If scaled from String 2, the commissioning of the circuits one by one for LHC would take 15 years. To reduce this time, several powering sub sectors are to be commissioned in parallel. To further increase the efficiency for commissioning, several circuits will be commissioned in parallel. This requires automated test procedures that drive the quench protection system, the powering interlocks and the power converters. Detailed specifications are being written [4]. Implementation will be done by LSA and the Controls Group, based on existing tools where possible. Software for the quench analysis used in SM18 may be reused.

Other groups are making important controls contributions for hardware commissioning:

- Controls for the vacuum system based on industrial PLCs and SCADA is done by AT-VAC.
- Control crates for the quench protection system are the responsibility of the AT-MEL group.
- Embedded and gateway control for the power converters are under the responsibility of AB-PO.
- The AB-OP group has large responsibilities for control room application software.
- Instrumentation control for the ring cryogenics system is developed by AT-ACR. A particularly critical resource is the manpower for writing software specifications and then translating the specifications into PLC and PVSS code. This is aggravated by the increasing level of parallel activities being planned.

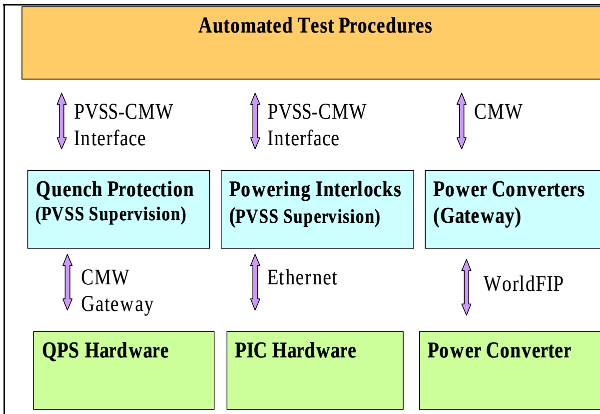

Fig. 2: Hardware commissioning: systems and their communication for automated test procedures

MILESTONES AND DELIVERABLES

Table 1 gives the deliverables for the different milestones, ordered by time. After TT40 and TI 8 the next milestones are LEIR beam commissioning and the first tests of the QRL. In yellow, the milestones for hardware commissioning are given ("String 3" and large electrical circuit commissioning). By then, most of the deliverables should have already been deployed for other milestones. The automated test procedures will be required for the first time during the "String 3" tests.

Table. 1: Deliverables for the different milestones

	Field control room	Post Mortem	Logging	Timing	Alarms (LASER)	Powering Interlocks	PC control	Automated Test Procedures	OASIS	CMW / FESA / LSA	PVSS / UNICOS
TT40 / TI8	NO	NO	YES	Partial	NO	YES (WIC)	YES	NO	YES	ALL	YES
LEIR beam commissioning	YES	NO	YES	YES	YES	YES (WIC)	YES	NO	YES	ALL	YES (vacuum)
First QRL tests	Maybe	NO	YES	NO	YES (?)	NO	NO	NO	NO	NO	YES
QPS surface tests	NO	YES	NO	NO	NO	NO	NO	NO	NO	FESA	NO
Test DFB in SM18	YES ??	YES	YES	NO	NO	YES (PIC)	NO	NO	NO	FESA	YES
Test LSS8L ("String 3")	YES	YES	YES	YES	YES	YES	YES	YES	NO	ALL	YES
Large electrical circuit commissioning	YES	YES	YES	YES	YES	YES	YES	YES	NO	ALL	YES
SPS / TI2 / CNGS	NO	?	YES	YES	YES	YES (WIC)	YES	NO	YES	ALL	YES
LHC sector with beam	NO	YES	YES	YES	YES	YES	YES	YES	YES	ALL	YES

RECORDING DATA

There are several systems used to record data. The logging system will be used for the lifetime of the LHC, to record data in regular intervals, or on change. In order to record data during LHC filling, the shot-by-shot logging has been implemented. Data capture from various clients is synchronised with the accelerator timing; the data are stored in the logging system.

	Used where?	Name required	Timestamp required	Stores data after event	Stores data in regular intervals / on change	Stores transients (vector of data) after event
Logging system	LHC and other accelerators	YES	YES	via SbS Logging	YES	NO
Shot-by-Shot Logging (one of the clients for logging system)	LHC filling	YES	YES	YES (event)	NO	YES
Alarms	All accelerators	YES	YES	YES (fault condition)	NO	NO
Post mortem recording	LHC operation	YES	YES	YES (event)	NO	YES

Fig. 3: Systems to record data

Both systems were employed during TI 8 / TT40 tests and were essential for the reconstruction of an incident leading to the damage of a vacuum chamber and a quadrupole magnet [5]. The alarm system (LASER) will become operational in the next months for LEIR.

Some post mortem recording has been done using the above systems. Post mortem analysis will require data from all of these systems together with transient recordings and settings data from the LSA databases. The responsibility for providing information is with the client systems and adherence to standards for naming and time stamping is essential.

CONCLUSIONS

Control systems are required, not only for the LHC but also for all other accelerators projects at CERN. Similar to hardware systems, there are differences of controls between accelerators due to different requirements, but also due to different implementations. Two years ago there were three Accelerator Controls Groups, now there is only one. A limited variety of solutions have been selected pursuing standardisation as far as reasonable.

The general strategy is to implement these solutions progressively. This effort started already in 2003 for the TT40 tests, continued in 2004 with SPS and TI 8, and will further continue with many intermediate milestones between now and LHC beam commissioning.

Milestones for validation of controls for hardware commissioning is via the QRL tests, the QPS Surface tests, the DFB tests, "String 3" comprising two small powering sub sectors and then the other 26 powering sub sectors and the injection test. This gives us the chance to start the most critical phases of LHC commissioning with well-tested and efficient controls.

For hardware commissioning, critical issues are:

- getting the controls hardware installed and tested
- post mortem recording and analysis
- automatic test procedures
- integration of controls efforts with other groups

Milestones for validation of controls for beam commissioning are via LEIR, SPS, LHC injection test, TI 2 and then finally LHC.

Development, implementation and commissioning, should be done well ahead of the date when controls is needed with very high efficiency. Dry runs must be scheduled and performed for all major steps in the commissioning.

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