HARDWARE COMMISSIONING

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Abstract

Following the uncertainty of the installation schedule, the Hardware Commissioning Working Group (HCWG) focussed on the commissioning of two sectors around an even point in parallel, augmented by a number of additional constraints. This exercise, which was published as a Management Report [1], yielded commissioning times and resource needs which can be scaled -within reasonable limits- to the requirements of the final installation schedule.

Both the durations of the different phases and the personnel required have been estimated in the light of previous experience at the String and during Hera commissioning.

The current trend of reducing the time available for hardware commissioning cannot continue indefinitely. The hard limit is reached when the time taken by the test procedures and by the result interpretation cannot be further shortened but also when additional resources to obtain shorter times cannot be added.

The paper describes how the evaluation exercise was conducted, focuses on the test procedures, quality assurance and decision making process, proposes alternative strategies for deploying additional manpower and finally emphasizes the need for first-rate service from the infrastructures and software applications.

INTRODUCTION

The incidents which occurred during the installation of the cryogenic line in sector 78 have resulted in the compression of the planned installation schedule [2] because the originally planned delivery date of the collider for operation is not expected to be affected. In order to achieve this, a drastic reduction of all the activities is needed: this includes all the installation and assembly activities as well as the commissioning of the hardware before green light is given for the operation with beam.

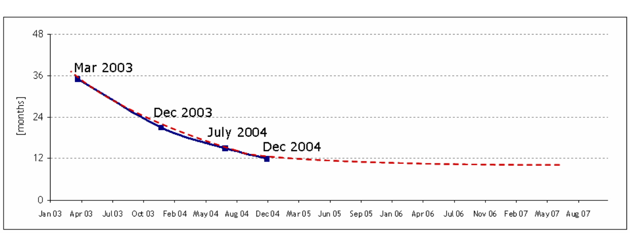

Figure 1: Time allocated for Hardware Commissioning.

The figure above shows the evolution of the time available for hardware commissioning during the past 20 months: it constitutes the main justification of the study since most of the concerned Group and Activity Leaders realized they did not have the resources necessary to carry out the task in the given time.

A study was conducted to summarize the activities, the time required and the manpower involved in hardware commissioning starting form a number of basic assumptions: from this study, which was published as a report, it is possible to derive the resources needed for a different scenario when some of the restrictions are lifted or relaxed and/or shorter commissioning times are requested.

The study is focussed on the superconducting electrical circuits. While the HCWG is aware it is not the only equipment that needs to be commissioned, it believes the superconducting electrical circuits will dominate the scene.

The individual commissioning activities for almost all the other machine subsystems have been studied but an overall commissioning programme has not been prepared yet: it strongly depends on the installation schedule.

BASIC ASSUMPTIONS

The following basic assumptions have been made. They determine a certain commissioning scenario and the resources required for it:

- Parallel commissioning of two sectors (not more, not less) around one even point.
- Five-day working weeks
- Two shifts during the powering tests
- Two commissioning fronts on each sector during the powering tests: one front attacks the arc and the matching section on the even side and the other the arc, the matching section on the odd side and the inner triplet(s)
- An operation team is present in the field during the two shifts of powering tests: it is composed of one AB/OP operator and one member of the Hardware Commissioning Coordination
- The magnets are left floating in temperature after the commissioning of a sector.
- The RF system is commissioned during the six months preceding the commissioning with beam in the machine as described in LHC-A-HCP-0001 [9]. Only in this case all the resources required for cryogenics (operation crews and instrumentation commissioning) are available.
- The PS complex and SPS run in 2006.

It is never enough emphasized that changing these assumptions have a direct impact both on the number of teams (hence the resources) and the feasibility of the exercise following safe and professional quality standards. Because of the large energy stored in the coils, this is particularly important for the superconducting electrical circuits.

THE TESTS FOR THE SUPERCONDUCTING ELECTRICAL CIRCUITS

Four phases can be identified: they are listed below together with the activities which take place during each phase:

1 Individual System Tests at warm
- validation of subsystems, connectivity, computer networks and field buses, timing, supervision, etc.
- validation of the instrumentation and subsystem functional tests
- electrical quality assurance
- short circuit tests, interlocks

2 Cool down
- calibration at cold and cryogenic loop tuning
- electrical quality assurance

3 Tests at cold
- electrical quality assurance
- quench protection

4 Powering Tests
- validation of the interlocks
- validation at low, nominal current and all circuits in unison

The latter two phases take place at the same time once the magnets are cold.

With the basic assumptions, resources for the same type of activity have been planned only for two sectors. This does not exclude the possibility of a staggered commissioning of another set of two sectors as long as the same activity is not taking place on more than two sectors. This implies that the teams involved in the Individual System Tests at warm should not be redeployed on activities taking place during the powering tests or the tests at cold.

The powering tests

While the first three phases include mostly activities which are carried out by the groups individually, the forth phase consists of tests which involve many groups. The powering tests are divided into two major phases which are differentiated by the *non connection* and then by *connection* of the power converter to the superconducting circuits.

During the first set of tests the systems, namely, the power converters, the quench detection system, the energy extraction system and the interlocks, are validated first independently then in conjunction. During the second phase, after a validation at low current of the interlock system, the circuits are gradually powered up to nominal current: at predefined current levels a set of tests is carried out. The aim and the description of all these steps are given in [3].

The Circuits

In order to determine the time needed to commission all the superconducting electrical circuits, five categories of circuits have been defined and typical commissioning times attached to each type of circuit.

It is worthwhile mentioning that the 752 orbit corrector circuits, which are locally powered by converters situated under a central dipole of each cell, have not been counted in the table below: their commissioning will have to be carried-out together with the others and must be considered to be an additional front.

Table 1: Circuit types and commissioning time

Type	**Number**	**15-hour days needed each**	**15-hour days needed total**
Main dipoles	8	11.00	88
Quadrupoles (Arc, DS, IT)	32	5.50	132
Separately powered quadrupoles	78	1.73	135
600 A circuits, separation and recombination dipoles	436	0.84	366
80-120 A orbit correctors, IT correctors	274	0.31	85

Table 1 shows that 806 15-hour days will be needed to commission the 828 circuits. However, the basic assumptions consider the commissioning on four fronts (two per sector, two sectors in parallel) therefore, the time required for the power tests is estimated to be 201 15-hour days of a 5-day working week, i.e. one year.

The manpower deployed by the different groups in the AB, AT and TS Departments in the tunnel for the powering tests amounts to 22 persons the specialty of whom is given in [1] together with a description of each activity at any given time. This staff is supported by people on-call either during working hours or 24h a day.

The four fronts imply that the 22 persons in the field commission four such circuits plus a set of orbit correctors at any given time. The total time for the two sectors on either side of an even point is estimated to be on average 12 weeks.

MANPOWER CONSIDERATIONS

The study [1] concluded that given the basic assumptions, 142 operators, technicians, engineers and experts from the different groups in the AB, AT and TS Departments will be involved in the commissioning activity spanning from the individual system tests of each system to the powering tests. It also concluded that, given the basic assumptions, 46 of these are missing and must be hired or detached from national laboratories; these should become involved during this year to ensure proper training in view of the beginning of the commissioning in June 2005.

The study also found that some activities lacked supervisors to coach junior or inexperienced staff through the commissioning activities. The study of alternative scenarios was therefore suggested: these include contracting firms with test and quality assurance missions for which very detailed technical specifications must be drawn up in the shortest possible delays. These will be indispensable also for the collaboration agreements to be made with the national laboratories.

SCHEDULE CONSIDERATIONS

The crude application of the basic assumptions yields a commissioning schedule which requires 28 months to complete the activity. After a first optimization which implies some minor overloading of a few teams, the calendar of 20 months is found possible. This is the scenario where 142 people are required. As shown in Figure 1, the present provisional schedule assigns 12 months from the start of the hardware commissioning activity to the start of the machine checkout preceding the commissioning with beam. Therefore, the count of the missing staff for commissioning must be reviewed and the feasibility of the commissioning in 12 months must be re-assessed.

In this context, options like partial commissioning of the sectors (e.g. postponing the commissioning of circuits not needed for the first run of the collider), and a review of the commissioning procedures must be envisaged. However, the fact that large energies stored in the circuits must be kept in mind before any simplification of the procedures is considered.

TOOLS FOR HARDWARE COMMISSIONING: THE SOFTWARE

The very tight schedule can only be kept if significant support from groups providing informatics tools is secured. The tools which are required for the commissioning include applications for quench signature recognition and battery tests of 600 A circuits.

In order to specify the application software required for Hardware Commissioning, a sub working group has been set-up in conjunction with the Controls Group of the AB Department. A detailed description of the functionalities of applications together with an implementation schedule compatible with the needs for commissioning will be published.

In addition, since the MTF will be a core application during commissioning, its optimization to include schedule information, the description of the test steps and the storage of the test results is mandatory. The integration of the databases containing the test results and of calibration data with the MTF is also required.

An Engineering Specification [4] describing the functionalities of the MTF required for Hardware Commissioning was published: contacts with the CSE Group in charge of the MTF are on going to follow-up the implementations of the required functionalities.

Again, it is worthwhile mentioning that any glitch in the supply of this support will jeopardize the success and timely completion of the commissioning.

THE PROGRAM FOR 2005

The installation schedule presented at the TCC in November foresees the installation of the three machine sub sectors left of Point 8 and the complete QRL in sector 78. This permits the commissioning of the sub sectors during the last months of 2005 and early 2006, before the sector is completed. It concerns the inner triplet, the two separation/recombination dipoles, the DFBX, Q4 and Q5 all left of Point 8. The equipment is situated in RA83 just on the other side of the wall from UA83 where the field control room will be installed.

In order to achieve this, all the individual system tests of the cryogenic instrumentation, the power interlock controllers, the quench protection system and the power converter short circuit tests must take place in the second half of 2005.

Discussions with the groups concerned are ongoing to secure the feasibility of this proposal.

CONCLUSIONS

The resources for hardware commissioning deserve attention. The study which was carried-out shows that, with the present staffing, the groups involved cannot carry out the hardware commissioning in 20 months and therefore neither in 12 months. The latter figure however, is the most one can expect will be available. Furthermore, the situation in some groups requires a change in strategy since the resources for the supervision of the tests are not available.

The study of the commissioning procedures and their duration was completed and revised; the validation of the times can only come after the first sub sectors are commissioned.

REFERENCES

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