HOW TO IMPROVE OPERATIONAL EFFICIENCY?

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Abstract

At the end of 2009 we had 26 days of successful beam commissioning. Nevertheless, the period also revealed a number of possible weaknesses in various aspects of the LHC operation: procedures, tools, discipline, equipment and organisation, which were discussed during the talk *What are the weak points of operation?* by B. Goddard. This paper tries to quantize in which points the operational efficiency was low such we have a criterion to establish priorities, and how to improve them.

REASONS FOR MACHINE UNAVAILABILITY

Analyzing the e-logbook from the 20th of November to 16th of December 2009 (the beam commissioning period) we can draw the following picture: due to different problems, that will be explained in the following, the machine was not available for injecting beam 40% of the time (Figure 1).

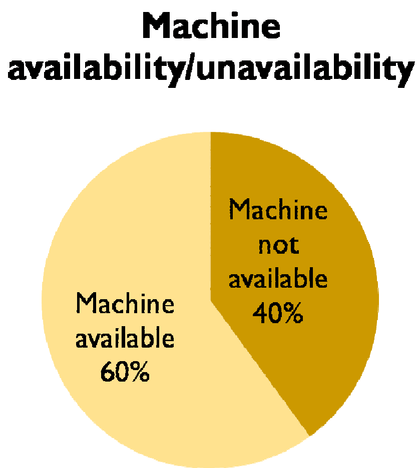

Figure 1: percentage of machine availability/ unavailability during the 26 days of beam commissioning in 2009.

Different problems are responsible for this 40%. The percentage of down time per problem normalized to the 40% can be found in Figure 2. As can be seen, cryogenic problems are responsible for 23% of the down time (including the corresponding access in the machine to fix the problem). Pre-cycle side effects account for 18% of the time, which means:

- Non correct settings which was solved at the beginning.
- Power converter problems (some occasions access needed)
- QPS problems:
    - Not possible to reset with power cycle ➔ intervention in the tunnel needed.
    - Trips due to U_RES drifting above 0 mV.
    - Noise induced by RBHI in TI2 tripped the nQPS in sector 12.
- RQTD, RQTF trips in the whole machine because tune feedback was left over.

QPS specific problems gave 10% of the down time:

- Access in the machine needed to increase thresholds on global bus bar detectors.
- Access to reset circuits that could not be rested from the CCC.
- Access to replace heater discharge power supply in sector 34.

The LHC experiments gave a contribution of 3%:

- Lost patrol (2 hours)
- Up to 20 minutes to analyze post mortem events and give back the injection permit.
- Problems to give the injection permit (4 hours)

There is a 5% due to miscellaneous reasons:

- Emergency access.
- A combination of pre-cycle problems, cryogenic lost and then access needed.

The rest of the problems quantized in Figure 2 can be considered as problems expected during commissioning phase of the machine and the equipment and they were solved. But the list of problems explicitly mentioned above are not yet solved and we should do something about.

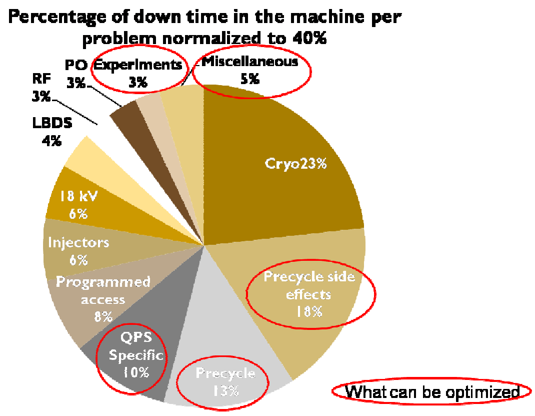

Figure 2: Percentage of down time in the machine per problem normalized to the 40% of machine unavailability.

PROPOSED SOLUTIONS

Wrong settings

In order to test thoroughly the settings we should exploit the dry runs, however for this we need the power converters and the QPS system fully available, the SIMULATION mode is not sufficient since it only tests the Function Generation (FGCs) part.

QPS remote reset

Although remote reset is available for all sectors for some reasons not always work, we should understand why and fixed it, otherwise access to the machine is needed each time.

U_RES reset

A PVSS method (accessible via a sequencer task) that resets the U_RES (the residual splice resistance) drift once per day could solved the problem.

TI2 – Sector 12 electromagnetic coupling

As a palliative measurement the thresholds in the nQPS for sector 12 were increased from 300 µV to 500 µV, and at the same time the RBHI in TI2 was systematically switch off before ramping sector 12. A definitive solution, however, to the electromagnetic coupling will have to be put in place because the palliative solution is not error free since we had the case once that wrong thresholds loaded and the sector tripped.

Tune feedback left over

The proposed solution consists on making the tune and the chromaticity feedback (FB) dependent on the beam presence flag (BPF) with the following logic:
automatic FB 'on → off' if BPF 'true → false'
FB 'off → on' only if 'BPF == true'

Heaters power supplies

We need a systematic verification of the heaters power supplies that could be implemented as an automatic task in the QPS system with the corresponding alarms when a heater power supply is not properly charged.

Problems with the experiments

- Procedures are not always known by the shift crew and the expert has to be contacted. This is fine during working hours, but at night, since the experts are not necessarily on call, may require a lot of time to fix. This could be easily solved with a better training of the shift crews.
- A few experiments take time (up to 20 minutes) to give back the injection permit after a beam dump produced by the machine. We should agree on a simplified procedure when we are doing beam commissioning with safe beam and the beam dump was not produced by the experiment but by the machine. May be this procedure has to be revisited when working with unsafe beam.

Fast access during beam operation

We need a procedure to simplify the access to the machine during beam operation which doesn't force us to switch off all the circuits. This will have the advantage of faster recovery from access.

MACHINE AVAILABILITY

The machine was available for beam operation 60% of the time. Out of this 60%, half of the time there was actually beam in the machine; the other hald was invested in:

- Preparation for injection: set up transfer lines, MKI soft start, handshakes, LBDS/BIC arming, etc.
- Understand the dump via the analysis of the post-mortem data.
- Solve problems (most of them mentioned in *What are the weak points of operation?* by B. Goddard, in this proceedings)

The majority of problems were solved within few minutes; therefore what matters is the occurrence of the problem. If the problem repeats systematically it is an indication that the control tools may not be adequate, or the procedures are not adequate, or the staff training is insufficient.

There are problems that we can afford to have them with safe beam, if they happen one or two times, but even at this low rate they may constitute an important issue when working with unsafe beam and therefore have to be fixed.

There are problems that they are not problems by themselves but because of the collateral damage they produce: powering-access interlock ➔ locks all power converters generating a fast power abort when they are powered above 1 kA (once the BIC loop is broken)

Most of the problems mentioned in *What are the weak points of operation?* by B. Goddard have a rather easy and straight forward technical solution like controls problems (FESA servers, proxies, etc). In what concerns the LHC Sequencer, a review took place the first week of January and a list of requirements with priorities exists and it is being implemented. Within the requirement list emphasis is given to prepare the sequencer for unsafe beam operation.

BLMs issues found in 2009 are being addressed/solved, and lot of work on reliability/monitoring of the healthiness of the system, as well as how to overcome the over-injection problem are under study and implementation.

But there are other problems that require a careful thinking, mainly the ones which solution has to be in place before unsafe beam operation. To cite some:

- **Injection mechanism**: improve software tools to assure correct injection (Injection Quality Check, injection sequencer, LHC sequencer), check entry conditions before injecting, clean-up the system after injection to be ready for next step, procedures/sequences, etc.
- **Beam dump analysis**: eXternal Post Operational Checks (XPOC) and Post Mortem analysis have to be finalized and extensively tested.
- **System specific problems**: we have to make sure they are addressed and solved. This needs

follow up within the appropriate framework like the beam commissioning meetings and dry runs.

- **Procedural problems**: need a major debate.
- **Operational discipline/training**

Taking into account all the problems, the presence of any of the beams in the machine during the 26 days of beam operation in 2009 is 30%. The beam presence day by day can be found in Figure 3.

CONCLUSIONS

If we manage to solve the solvable problems which make the machine unavailable we can recover 40-50 % of the down time.

If we manage to solve the problems which prevent us of having beam in the machine when the machine is available, we can recover ~15% of down time.

The means to do this exist. But when trying to maximize the beam availability time we should not compromise safety. Unsafe beam operation will imply less flexibility, more checks before injection takes place, more time to analyze the beam dumps ... Less beam presence in the machine.

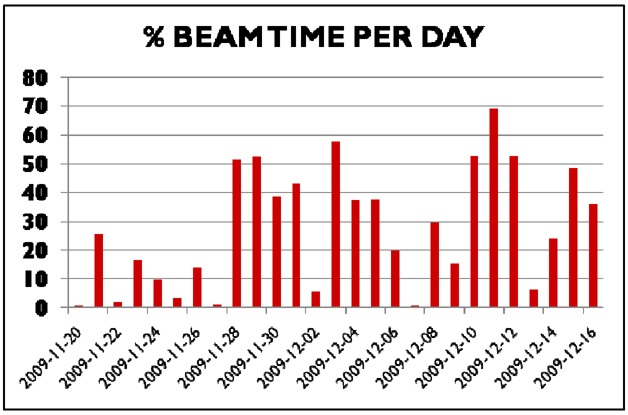

Figure 3: Percentage of beam presence in LHC per day, beam 1 or beam 2 (courtesy of C. Roderick)