SAFETY DURING POWERING TESTS

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Abstract

In this presentation safety of personnel during powering of superconducting magnets is discussed. A number of issues related to safety during hardware commissioning were already addressed during the LHC Safety Day on 18 October 2007:

http://indico.cern.ch/conferenceTimeTable.py?confId=22150

In particular, the procedures to ensure electrical safety when working on equipment remain in place (locking-off circuits etc.).

In this presentation lessons learned from the incident on 19/9/2008 are presented, and it is discussed how powering tests can be performed in the future.

ACCESS DURING POWERING TESTS

Before the incident 19/9/2008

Access to most underground areas of the LHC was in restricted mode. With a current in a circuit above 1 kA no access to the tunnel was allowed.

With a current in the circuits below 1 kA access for experts involved in the powering tests and for urgent interventions was possible. Access to the experiments was not restricted (the access condition were left to the choice of the experiments). Access to other underground areas in the sector was possible, if required for experts involved in the powering tests (UJ, UA, …).

After the incident 19/9/2008

Due to the breaking of helium lines and the insulation vacuum a large part of the tunnel in sector 34 was filled with helium. Even some hours after the incident no access for personnel was possible. In the light of this experience the access conditions during powering tests in autumn were redefined [1].

Access to the tunnel and other underground areas of the sector that was powered was not permitted, neither access to the tunnel of adjacent sectors, if there was no buffer between the sectors (such as an experiment). Experiments adjacent to the sector being powered could not be accessed.

Tests were performed during late afternoon and in the evening. Organising the tests required very heavy overhead and frequent patrols. It was a difficult period for the hardware commissioning team, shutdown coordination, operation and experiments. The efficiency of the tests was compromised.

Observation from the incident

The incident happened at a current of 8.7 kA, in a circuit that had not been powered to this current before.

In UA43 a ventilation door fell over due to the pressure increase in the tunnel and UA43.

The ODH detectors in UJ 33 did not show lack of oxygen. There are indications that there was no lack of oxygen in the underground areas at point 4, but since there are no ODH monitors in UA43 this cannot be proven.

Since no one was in the tunnel (current was above 1 kA), there was no risk for personnel.

A preliminary analysis of the data indicates that with such massive helium release oxygen deficiency was limited to the tunnel. The data from the incident needs to be further analysed, in order to better understand the propagation of helium in case of such massive release and the associated risk.

Powering test and tunnel access

One option for access would be as for beam operation, to finish all activities and to close the entire LHC before starting powering tests.

This would delay commissioning by several months. Since commissioning would be for all sectors during the same period, many activities would be performed in parallel. Still, frequent access for fixing problems would be required.

Some steps in the powering test procedures require access (switching off water for checking interlocks, qualifying energy extraction system,..).

The option of starting powering tests when all LHC is closed is not recommended.

PLANNING AND POWERING TEST

In the current planning [2] the first sector becomes cold by end April and the last sector by Mid August. If rules for access remain as after 19/9/2008, powering tests cannot start before mid June, although the cryogenic conditions would permit start of powering about six weeks earlier.

The exact duration of the powering tests can only be determined after the procedures for powering are updated, taking into account the upgrade of the QPS system and possibly the introduction of other steps to minimise the risk to equipment.

Powering tests and other activities will be performed in parallel, depending on the sector. The access mode will therefore depend on the sector.

During shutdown, access is in general mode and the responsibility is with shutdown coordination. In this

mode, the first option is that all people can access that are included in a general list. A second option is that only those people can access that are in a restricted list (updated daily), as done for sector 34 after the incident.

This access mode has the advantage that no operators are required to give access.

Access will change from general to restricted or closed mode:

- During (first) cool-down.
- During powering tests and machine-checkout.

This mode needs an operator to give access.

There is a transition from shutdown to commissioning / operation (including powering tests, machine checkout and beam operation), the responsibility is with commissioning and operation.

- Powering tests: restricted/closed (coordination of access by hardware commissioning team)
- Machine checkout: restricted/closed (coordination of access by machine checkout team)
- Beam (coordination of access by machine coordinator + EiC)

For sectors that have been warmed up, the transition from general access to restricted access is before ELQA-HV qualification at warm. Afterwards the sector remains in restricted mode.

For sectors remaining cold, the transition is either before ELQA HV tests, or when electrical systems are unlocked (power converters, QPS heater power supplies).

In restricted mode, access requires an ADI (Avis d'Intervention) for all scheduled interventions (approved by point owners). However, some interventions cannot be scheduled:

- Interventions that are related to the tests (for example, the QPS team needs to access their equipment)
- Interventions that are urgent (for example, for vacuum or cryo teams to ensure correct conditions)

In this case the EiC on shift takes the decision if access is granted (with input from point owners, and/or informing the point owner).

If there is a long interruption of the tests (at least a few days or weeks), there are several options:

- Continue with restricted access, requiring an ADI and an operator to give access.
- Restricted list automatically filled from ADI (when signed). The feasibility needs to be checked.
- General mode with restricted list at Personnel Access Door (PAD) level (LHC-TNL34 like that was used for sector 34).

It needs to be clarified what to do in case of urgent access, for example, for a piquet or for the replacement of a member of a team with ADI permission.

It might be envisaged to group accesses, for example, one day per week reserved for access, and the rest of the week reserved for powering tests and NO access (except if required for urgent interventions related to the tests).

CIRCUIT TYPES AND PARAMETERS

The risk for massive accidental helium release depends on the circuit type, on the commissioning step (current and energy stored in the circuit) and on the circuit location.

Types of circuits:

- orbit corrector magnets (max. current 60A)
- orbit corrector magnets (max. current 80-120A)
- corrector magnets (max. current 600A)
- quadrupole and dipole magnets (some kA)
- main dipole and quadrupole magnets (max. current 12kA)

Locations of circuits

- installed in the continuous arc cryostats
- installed in stand alone cryostats
- installed in triplet cryostats

A large fraction of the tests is being done at low current (e.g. tests of the interlock systems, …..). Experience shows that debugging of the systems requires frequent access, in particular during the tests at low current.

PHASES DURING THE POWERING TESTS

It is suggested to introduce two phases of powering tests for a sector.

PHASE I - Low current powering tests: the current in a sector is limited to a value with negligible risks of massive accidental helium release due to powering.

- Underground access is in restricted mode.
- Limitations for access to tunnel is closed or restricted, to be discussed.
- No limitations for access to experiment.
- No limitations for access to adjacent sectors.

Normally, tests are being done with no personnel in the sector, but access can be granted if required.

PHASE II - High current powering tests: the current in the circuits is not limited.

- Access is closed & all necessary areas patrolled.
- Access to experiments needs to be defined.

For each circuit type it is required to define the limit between "Low Current" and "High Current". When a sector is in PHASE II the definition of what areas need to be closed and patrolled is required, such as adjacent tunnel areas, service areas and experiments (by the Task Force discussed in [3]).

It is the responsibility of the EiC on shift to ensure that no one is present in the areas during high current powering.

Risks during powering phases

The risk during Phase I is if the current is increased above the limit AND there is failure that leads to massive helium release AND there are people in the tunnel.

The method of ensuring the limitation of the current needs to be defined. It must be simple to verify this limitation.

The risk during Phase II is if someone enters the closed area (violating the rules) AND a circuit is powered at high current AND there is a failure that leads to a massive helium release.

It must be made sure that no one enters accidentally into the area.

The EiC needs tools to have a clear view:

- Are the areas concerned by high current powering tests closed?
- Is the current during low current powering tests below the limit?

There are two options to start powering in powering phase II:

- Patrol is SAFE
- Envelop doors are all closed, emergency handles armed and no key is taken at any of the relevant access points

If the current in a circuit exceeds the limit, what to do? Interrupt the test? How?

During powering phase II, if there is an intrusion to closed areas, what to do: Interrupt test? How?

POWERING PHASES DETAILS

Phase I at low current

- A sector is defined to be in "Powering Phase I".
- The current in the circuits in the sector is limited.
- The underground access of the concerned areas is in closed or in restricted mode.
- Access can be granted to these areas to people involved in the powering tests and for urgent interventions.

The method ensuring the limitation of the current needs to be defined (possibly using hardware limitation on the power converter and/or FGC parameter). It must be easy to verify this limitation. Only authorised people can change this limitation.

The access conditions and the powering phase derived from the current are shown on a screen. If the access conditions and the maximum current are not compatible, powering could be stopped performing a Slow Power Abort via the PIC.

Phase II at high current

- A sector is defined to be in "Powering Phase II".
- The current in the circuits is not limited.
- For each sector, the areas concerned by the powering tests need to be defined and the access mode of these areas is 'restricted' after a patrol has been done, and no access will be given.
- The access conditions are published and the powering phase is shown on a screen.
- If the access conditions are not compatible with this phase of high current powering, a warning is issued. It could be envisaged to stop powering, the detailed mechanism needs to be defined.

If there is any violation of the access zone, the question should be addressed if people can be informed (by sirens? Other means?) .

CONCLUSIONS

Two phases of powering are suggested, powering at low (limited) current, and powering at any current.

It is essential to define the matrix between the powering phase and the areas with restricted or closed access.

Circuits with normal conducting magnets are not considered in this presentation as there is no risk for helium release and electrical protection is done according to IP regulations.

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[2] K.Foraz, J.Coupard, Shutdown Modifications 2008/9 and Future shutdowns, these proceedings

[3] G.Roy, Consequences for safety of personnel following S34, these proceedings