199th Meeting of the Machine Protection Panel

Injectors topics

November 27th, 2020 via Zoom

Participants:

Jan Borburgh (TE-ABT), Andrew Butterworth (BE-RF), Cedric Hernalsteens (TE-MPE), Verena Kain (BE-OP), Bettina Mikulec (BE-OP), Richard Mompo (TE-MPE), Filip Moortgat (EP-UCM), David Nisbet (TE-EPC), Joao Carlos Oliveira (BE-RF), Brad Schofield (BE-ICS), Andrzej Siemko (TE-MPE), Rende Steerenberg (BE-OP), Jan Uythoven (TE-MPE), Christoph Wiesner (TE-MPE), Daniel Wollmann (TE-MPE).

The slides of all presentations can be found on the website of the Machine Protection Panel and on Indico (199th meeting).

Minutes from the 197th MPP meeting (Injectors topics)

- The actions regarding the connection of the POPS-B to the BIS and the BIS GUI for the injectors have been clarified. The following actions replace the original ones and the minutes have been updated:
  - Verify how the connection has been done between POPS-B and BIS and describe the user input to BIS (F. Boattini, EPC).
  - Organize a discussion on the BIS GUI for the injectors (J. Uythoven).
- With these changes, the minutes from the 197th MPP are approved.

SPS RF interlocking (Andy Butterworth)

Andy first introduced the RF upgrade that took place in the SPS during LS2. The 200 MHz travelling wave cavities (TWC200) have been removed from the SPS, dismantled and reassembled. Two new cavities have been added, for a total of six reinstalled cavities. Two new additional power amplifiers are needed for the two additional cavities. New solid-state amplifiers (from Thales) are powering the new cavities. The existing Siemens and Philips amplifiers (tetrode tube amplifiers) are powering two cavities each. A complete renovation of the low-level rf (LLRF) system was also performed. The analog and VME beam control systems have been replaced by a fully digital microTCA-based feedback system. New electronics is installed for the pickup and cavity controller front-ends.

The RF power interlocks limit the maximum power to avoid damage to the hardware (in particular for the Thales solid state amplifiers which are quite sensitive). For this, a set of interlocks with different timescales is put in place. A digital clamping of the rf drive (in the low-level RF) checks the peak power (10 ns average) and reports an alarm as a functional limit, not a protection interlock). A peak power interlock with a delay of a few tens of microseconds will switch off the RF. Similarly, an average power interlock (timescale of 10 s, implemented in a PLC) can switch the RF off. Internal amplifier interlocks are also in place on the average power (200 ms averaging).

The fast interlock system is based on Beckhoff fast interlock modules in the PLC. The hardware logic is independent from the CPU of the PLC. The interlock chain has been tested and accepted (38 microseconds latency from input to output). It is deployed in the Thales systems and is under test. These interlock modules are also installed in the Siemens and Philips systems. The power signals for these are not yet available but will eventually only be used for the average power interlocks (the amplifiers are protected by internal interlocks on the peak power).

The slow average power interlocks are implemented in the PLC. The analog inputs are installed in the Siemens and Philips PLCs and will be shortly installed in the Thales PLCs. The average power measurements will be published on FESA.

Andy then presented an overview of the RF beam interlocks. These interlocks are foreseen for four different cases:

- protect the Thales amplifiers from reverse power,
- protect the pickup analog front-ends from overvoltage, pre-empt beam loss in case of RF trip during the ramp
- inhibit injection if an incorrect reference clock is selected ("LHC REFERENCE" must be selected if a dynamic destination (TI2 or TI8) is selected).

A beam interlock concentrator and the CIBU are installed in the Faraday cage in BA3. It has one input for each cavity interlock. A new fast interlock crate will replace the old beam dump interface crate and alarms PLC. It provides greater flexibility, monitoring and remote control. It is possible to mask interlocks in case of cavity downtime to allow a degraded mode of operation with lower intensity beams. The management of the masks could be done via critical settings.

For the Thales amplifiers, the interlock behaviour acts as follow: if a module trips or if the RF power limit is exceeded, the RF switches off and the beam is dumped. The interlocks are latched: the operator will have to make a reset. The PLC will automatically switch off the faulty modules. As long as a given number of modules (determined by RF experts) are still available, the operator can switch the RF on again and the beam permit is restored. If fewer modules are available, the RF stays off. If the RF expert decides to switch all modules offline (16 towers off), the RF switch will remain off but the beam permit will be automatically restored, as the equipment is in a safe state. The SIS could be surveying the total power and interlock in case the power is not sufficient and would need to be masked to continue operation with reduced power.
A similar logic applies for the Philips and Siemens amplifiers.

Question: Daniel asked what happens if additional modules are degrade. Andy replied that the same logic applies again. The minimum number of modules can be adjusted by experts.

The RF power interlocks will be integrated into the existing RF PLC FESA class. The PLC acquisitions will also be available in the FESA class. The fast interlock thresholds management is set in hardware. For the "slow" PLC interlocks, expert settings are available (also readable by OP).

The hardware integration and PLC development of the beam interlock concentrator and Faraday cage alarms are starting. The new FESA class needs to be written.

Questions and comments:

- Jan asked who can access the expert mode to switch off all the modules. Andy replied that switching everything off could also be performed by the operators, as this puts the line in a safe state. Carlos confirmed. Andy added that in case of reduced available power the decision to run with lower intensity beams is an operational decision and a procedure should be followed.
- Verena commented that in case of an RF state change during the cycle, a beam dump will occur. If all the modules are switched off, then the RF is self-masked, and the beam permit is restored. Then, the SIS will provide an interlock because the RF power is reduced. The SIS can provide further interlocking for high-intensity beams in case of reduced RF power.
- Daniel asked when the logic for the masking will be finalized. Andy replied that it can be decided immediately. Carlos confirmed that the latching of the amplifier can be implemented. Jan commented that it makes sense if this is handled with a procedure.
- Verena commented that the SIS interlock should not necessarily have the option to be masked but could use additional logic from the cycle (beam type, etc.) to allow the beam injection.
- Verena stated that we should avoid masking on the HW side, if possible. Instead, she proposed to implement a SIS check that, in general, requires all RF lines to be OK, but allows to mask the check for single RF lines. Andy added that the rules could be more detailed, e.g. defining how many lines are required for which type of beams. The SIS could implement the logic to decide, based on the cycle name, which type of beam it is and if it can be provided with limited RF power. Jan commented that, in addition, beam losses caused by insufficient RF power should be caught be the BLMs. The SIS checks can be implemented in as second stage without being a protection issue, as the BLMs provide a first safety net. This proposal was supported by the MPP.

WIC delay for switching off equipment for the PS (Richard Mompo)

Richard first provided an overview of the WIC system. The WIC is a generic solution for the protection of resistive magnets. It is based on Siemens PLCs. It is now deployed over the whole accelerator complex. It collects inputs from thermo-switches, flow switches and internal power converter faults. It provides permits to the power converters and to the BIS. In case of a magnet overheating, the WIC will request a beam dump to the BIS or inhibit the next beam, in case of a transfer line. After a configurable delay (typically 1.2 s), it removes the power permit of the power converter. The goal of introducing that delay if to allow for a clean beam extraction before ramping down the magnet current. The response time of the WIC is not an issue for the resistive magnets in general. This configurable delay is common to all the circuits connected to a given WIC.

Since 2016, with ELENA, other types of equipment are protected by the WIC. These include, the septa of ELENA, of the PSB and of the PS. As there is no BIS for the PS, the WIC does not remove any kind of beam permit for the PS. The magnetic septum of the slow extraction to the East Hall (PE.SMH57) has been identified as a critical element due to the high current density in the coils.

A standardized WIC interface is in place for all the septa and bumpers in the PS. Three inputs are present: the thermo-switches (TS), the flow-switches (FS) and a generic input coming from the ABT control PLC. The TS and FS signals are connected in parallel to both the control PLC and to the WIC (by means of safety relays).

Due to the high current density of PE.SMH57, ABT has implemented a fast interlock system which is connected in place of the "TS" input signal to the WIC. The maximum current supported by the septum is 5kA while the power converter can deliver up to 10kA DC. A dedicated fast interlock system has been put in place which measures the voltage and current to calculate the temperature-dependent internal resistance of the coils. The interlock signal is sent at the end of a pulse to avoid switching off the power converter during a pulse. For PE.SMH57, a 1.2 s response time of the WIC becomes an issue. The response time of the PLC depends on three parameters: the PLC cycle time, the profibus cycle and the IO sampling rate. This leads to a response time for the PS WIC between 140 and 340 ms. Adding the additional 1.2 s delay is then seen as problematic for the protection of the septum.

It has therefore been decided, following a request by TE-ABT, to remove the 1.2 s WIC delay. This implies that the delay will also not be present for all the other equipment connected to the "PS_Aux" WIC. It must be determined if the remaining WIC reaction time is acceptable for the protection of PE.SMH57 and if it is an issue, in general, to remove the delay for the other circuits connected to the same WIC (both points are discussed below).

Discussion, questions and comments

Jan B. confirmed that the WIC delay (up to 340 ms) is acceptable for the protection of PE.SMH57. The current pulse is around 800 ms. Adding 340 ms it gets close to 1 s, which is fine. However, it is a DC power converter, and it cannot be guaranteed that the PC will switch off correctly after its nominal pulse. Two protection mechanisms were put in place: the fast interlock system described above, and an internal Irms internal protection (the PC will ensure that the pulse is switched off after about 1 s). After recent modifications, it appears that the last protection will not be used anymore, and that the protection is now fully dependent on the fast interlock provided by ABT. In that situation, it is not acceptable to wait for an additional 1.2 s, as irreversible thermal damage might occur. Richard added that, following the FGC3 upgrade, the Irms can be surveyed internally by the PC controller. Richard asked David if he can confirm. David confirmed that the new system allows for an Irms interlock.

Daniel asked if the removal of the delay is an issue for any other equipment in the PS. Richard replied that this must be determined by OP, based on the functions of the other equipment connected to the PS_Aux WIC.

As a follow-up to the meeting, Frank confirmed that the matter has been discussed within OP and that the removal of the 1.2 s delay is not seen as an issue for the PS. No delay was present with the previous system and the PS protection can tolerate one full beam pulse without risk of damage.

Jan B. commented that it would be possible to reintroduce the delay in case it can be guaranteed that the internal Irms interlock of the power converter provides enough reliability. David commented that it is a software parameter and does not provide enough reliability.

Jan U. commented that, for the machines without active beam dump, the delay is not needed. In addition, it is profitable for the protection of non-usual resistive magnets. Richard added that the 1.2 s delay was implemented in 2004, at the time of the WIC for the transfer lines between the SPS and the LHC. Daniel commented that it would be good to investigate if the delay still proves useful for the other machines.

Action: Discuss with equipment owners and OP in Linac4, PS and PSB if the 1.2 s WIC delay can be removed for the injectors upstream of the SPS and decide when this change can be implemented and update the specification accordingly (R. Mompo and J. Uythoven).

Summary of actions

The actions from the meeting are:

- WIC delay for switching off equipment for the PS:
    1. Discuss with equipment owners and OP in Linac4, PS and PSB if the 1.2s delay can be removed for the injectors upstream of the SPS and decide when this change can be implemented and update the specification accordingly (R. Mompo and J. Uythoven).