# WP2 Meeting #153

Tue 9 July 2019, 10:00 – 12:00

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| *Chair:* | G. Arduini |
| *Speakers:* | M. Bastos, X. Buffat |
| *Participants:* | A. Alekou, S. Antipov, E. Cruz Alaniz, R. De Maria, D. Gamba, G. Iadarodla, N. Karastathis, S. Kostoglou, E. Métal, G. Sterbini |

## AGENDA

The meeting covered two topics: an update on power converter specification and an analysis of instabilities in LHC.



## MEETING ACTIONS

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| **Davide, Miguel** | Proceed with the documentation of Power Converter specification |
| **Xavier** | Identify what measurements need to be performed in Run3 based on the present experience and what diagnostics is required by the end of 2019<br><br>Examine whether the growth rates of the observed instabilities are consistent with models |

# GENERAL INFORMATION (G. ARDUINI)

Minutes of the previous meeting have just been circulated and will be reviewed at the following meeting.

# 1 PC STABILITY AT THE END OF THE RAMP (M. BASTOS)

A proposal has been made to update the Power Converter (PC) specifications. It is based on separating the temperature effect for each of the PC classes and estimating it for each of the classes.

At low frequencies the PC performance is governed by its Analogue-Digital Converter (ADC) and the current measurement loop (DCCT). The latter measures high currents, up to 18 kA, and converts it into smaller ones, around 5 A. A change in the measured current therefore corresponds to a change in power dissipation in the DCCT leading to a thermal settling process in the device. Thus one expects the DCCT to have a slight thermal drift within first minutes after arrival at Flat Top (FT). Currently, this drift is included into the long-term PC stability numbers, making them more challenging for the manufacturers. Excluding the initial 5 min at FT, one can relax the 12h stability specification for the DCCT.

The newly proposed specification would have a separate parameter for the stability at the end of the ramp. For the Class 0 it corresponds to 0.5 ppm maximum absolute deviation, Class 1 – 1.5 ppm, Class 2 – 1.5 ppm, Class 3 – 3.0 ppm, and Class 4 – 6.0 ppm.

- **Gianluigi** inquired about the impact of the propose specifications on the tune drift. **Davide** quoted that the current 12h values lead to $2.5 \times 10^{-4}$ rms tune variation and $\beta$-beating of the order $10^{-3}$ and 2.5 % of beam sigma rms orbit jitter assuming the nominal - fully squeezed $\beta^* = 15$ cm optics. Therefore the proposed 5 min values would lead to about a % $\sigma_{beam}$ orbit drift and $1.25 \times 10^{-4}$ tune variation assuming $\beta^* = 15$ cm. The actual impact will be even lower, although it might affect the ability to perform precision optics measurements right after the end of the Ramp. Those values should be compared with the typical trim response of the tune feedback at the end of the ramp in LHC, which is in the order of $\pm 5 \times 10^{-4}$, corresponding to about $2.5 \times 10^{-3}$ $\beta$-beating according to Matteo Solfaroli Camillocci. **Gianluigi** concluded the impact seems to be acceptable and does not pose a problem.
- **Gianluigi** asked when the note on the updated circuit specifications from beam dynamics considerations will be published. **Davide** and **Miguel** reported it is work in progress, some aspects related to noise still have to be clarified. **Gianluigi** proposed to go ahead with publication in its present state, since it is needed as a reference document (Action: **Davide**, **Miguel**).

# 2 SUMMARY OF INSTABILITY OBSERVATIONS: IMPLICATIONS FOR HL-LHC (X. BUFFAT)

**Xavier** presented a comprehensive analysis of instabilities observed in Run 2, going through the stages of the operation cycle.

At Injection, weak instabilities in the Vertical plane, mostly affecting tails of bunch trains, were observed. The instability could not be fully mitigated by Q' or Landau Octupoles and is presumably driven by electron cloud (ecloud). The instability seems to disappear for higher beam intensities as demonstrated during an ecloud MD with 12-bunch trains of $1.8 \times 10^{11}$ ppb, in qualitative agreement with present day numerical models of electron cloud build up in the dipoles and quadrupoles.

During Ramp hardly any instabilities have been observed. Some transverse activity is rarely seen, which might be attributed a hardware issue of the ADT feedback system. Additional diagnostics will be implemented within the ADT in LS2 to diagnose this type of issue.

Multiple instability observations were gathered at Flat Top. For single bunches, octupole threshold measurements are in line with simulations predictions for negative octupole current, around 1.8 times higher for the positive polarity (could be caused by the effect of noise), and around 4 times greater for positive polarity without feedback. The latter seems puzzling since the discrepancy cannot be caused by ADT noise. Instability growth rate measurements give a closer result – less than a factor two faster than expected from impedance model. A relatively lower threshold at negative polarity might be explained by a greater population of distribution tails (will likely be cut in HL-LHC); no measurements of tail population is available. Also, fill-to-fill variation of longitudinal distribution may be behind the pure reproducibility of 2015-16 measurements around Q' = 0; and optics correction, in particular linear coupling and non-linear effects affecting the detuning with amplitude, is critical for coherent beam stability as seen in 2016.

For 25ns bunch trains, in 2017 the trains were observed to be more unstable than single bunches, presumably because for an ecloud effect. This instability could not be reproduced in 2018. Eventually, the instability threshold of bunch train seemed compatible with the ones of single bunches, with a weak dependence on the bunch intensity which remains unexplained. Some unexplained instability mechanisms also persist, including so called Ghost instabilities with bunch trains in 2017, which could not be stabilized by increasing the octupole current. A working hypothesis is that some of non-reproducible observations might be caused by noise acting at a particular frequency (for example 50 Hz harmonics).

Overall, Q' = 15 and 50 turn damper seems a robust setting for bunch trains at FT. For long-term stability (more than 10 min) a factor 2 octupole current margin is needed. It is advised not to have waiting times during the cycle, e.g. by colliding directly after the ramp also in the ultimate scenario, thus avoiding the squeeze.

Going to Collision, an instability caused by reduction of the octupole detuning due to beam-beam (BB) interaction was observed in 2012. Dedicated studies to investigate the minimum of Landau Damping were carried out during ATS MDs in 2017 and 2018. The instability seems to happen at $1.6\sigma$ separation when the beams are kept at the critical separation for more than 5 s. It can be avoided by crossing the minimum fast enough: the recommended rate for HL-LHC is less than 3 s from 2 to $0\sigma$. The instability can also be avoided by other means such as asynchronous collapse of separation bumps or using the same separation plane in both IPs.

- Regarding the discrepancy between predicted and measured octupole thresholds, **Gianluigi** inquired whether it would be possible to determine the growth rates of the instabilities to see whether they are consistent with models (Action: **Xavier)**.
- **Gianluigi** asked to identify what measurements need to be performed in Run3 based on the present experience and what diagnostics is required by the end of the year. The detailed procedures for the measurements should be specified to make sure to collect all the necessary information (Action: **Xavier**). **Xavier** replied a characterization of different parts of beam impedance is an important piece of information. **Gianluigi** noted the first priority shall be given to characterization at FT in steady state. **Sergey** stressed the importance to have a reliable measurement of Landau damping (estimated for the moment either with BTF or anti-damper). **Gianni** suggested to profit from the Van der Meer cycles are not very constrained to try and perform some of the measurements.
- **Gianni** suggested that the instability with trains seen is 2017 could result from a weaker scrubbing during operation with 8b4e beams in 2017 with respect to 48b trains in 2018.

*Reported by S. Antipov*