LHC Beam Operation Committee

Notes from the meeting held on 29th November 2011

List of Participants

1. Orbit Stability in the Squeeze (Jorg Wenninger)

J. Wenninger presented that since the setup of the squeeze to 1.5/10/1.5/3m in March 2011, the **rms orbit stability in the arcs is at the 100µm level**. This level of stability is adequate for standard operation up to the highest intensities. In combination with tight collimator settings, these orbit excursions however lead to **beam losses of the order of 1%** at the primary collimators in IP7. The rms orbit shows significant **spikes around the matched optics points**, which are very reproducible. These orbit excursions are mainly global betatron oscillations with a phase corresponding to **a perturbation in IP8**.
J. Wenninger explained the magnet current interpolation between matched optics points, which includes a parabolic round-off of the quadrupole circuits. This interpolation induces (by construction) beta-beat errors between the matched optics points. These optics errors lead to a **non-closure of the crossing and separation bumps** and thus to global betatron oscillations which are expected to be a major cause of the observed orbit excursions during the squeeze. Due to the large crossing angle, IP8 is expected to be the dominant source of the excursions.
Possible mitigation options are (among others) a parabolic round-off of the bump knobs, a feed-forward of the corrections based on simulated and/or measured orbit excursions and a higher orbit feedback gain in combination with a feed-forward of the feedback corrections.
During an orbit feedback test on 21st November 2011, the **orbit feedback gain was increased by a factor 10, which reduced the orbit excursions by a factor 5.** The vertical corrections were partially fed-forward.

Discussion:
S. Redaelli pointed out that the parabolic round-off applies only to quadrupole circuits. This implies that the inconsistency between quadrupole and corrector settings is maximal around matched optics points. S. Fartoukh replied that the inconsistency is only a second order effect to the optics errors.

S. Fartoukh pointed out that the MCBX settings could play an important role. In IP1 and IP5 they are very constant throughout the squeeze. Also in IP8 a squeeze down to 3m β* could be done with more less constant settings MCBX settings.

2. LHC Orbit-FB Bandwidth (Ralph Steinhagen)

R. Steinhagen explained the necessity and the design of the LHC orbit feedback. The algorithm is based on a singular-value-decomposition (SVD) extended by a Tikhonov/opt. Wiener filter in order to regulate large eigenvalues (regularized-SVD). He pointed out that for a monotonic system there is only one optimum, which will iteratively always be reached. This makes the LHC orbit feedback rather **stable to optics errors**. The number of iterations needed to converge is closely related to the feedback bandwidth, though.
R. Steinhagen pointed out that there are two **non-linear influences**: **Delays** (hardware and calculation) and the **dI/dt rate-limits** of the power converters. These can lead to wrong amplitudes and **phase-lags of the correction.** Latter **can implicate instabilities.** He showed that when operating with increased feedback band-width and encountering the dI/dt rate-limit, the system can easily become unstable, as happened during the squeeze of IP2 in fill 2313.
R. Steinhagen proposed to **use the orbit feedback with an increased bandwidth during test ramps and feed forward the corrections.**
R. Steinhagen showed oscillating real-time trims during fill 2331, which are probably because the circuit RPLB.UA27.RCBCVS5.R2B2 reached the region just below the dI/dt rate-limit where non-linear phase-lags become important.

Discussion:
S. Fartoukh asked if the feedback algorithm can take into account the amplitude of the corrections with a penalty factor as well. R. Steinhagen replied that **SVD by construction minimizes the rms amplitude of the corrections together with the rms orbit excursions.** S. Fartoukh asked if a **penalty factor could be given to the amplitude of the real-time trims for individual circuits which are close to the rate-limit.** R. Steinhagen replied that this is in principle possible (and done for the RCBX). Now penalty weights are given to eigenvalues rather than single orbit correctors though.

G. Arduini asked if it is possible to make the **orbit feedback bandwidth as an LSA trim parameter** configurable (like the transverse damper gain), in order to be able to reduce it when no fast orbit feedback is needed. R. Steinhagen replied that this is in principle possible, especially when bandwidth reductions are envisaged. He pointed out that for **high bandwidth the orbit feedback is no longer a linear system**, thus a bandwidth increase should only be done by a system expert.

Upcoming meetings:

Thursday, 8th December 2011 **9:00** in **30-7-010**: **LSWG (2012 MD planning)**

The LBOC team wishes

Merry Christmas and a Happy New Year!

Reported by Tobias Baer