FAIR Commissioning & Control Working Group

Notes from the meeting held on 20th April 2016

e-mail distribution: FAIR-C2WG-ALL at GSI.de, participants list

Agenda:

- Beta-Beat Measurement and Correction for SIS100 (jump below), V. Chetvertkova
- Correcting the Beam Optics: Orbit Response Matrix Analysis for FAIR (jump below), O. Kovalenko

1. Beta-Beat Measurement and Correction for SIS100, V. Chetvertkova

In her presentation (see slides), Vera provided a summary and introduction to the topic of beta-functions and beta-beating. Due to magnet field errors and misalignments the actual beta-function may deviate from its nominal design. Since the beta-function – together with the emittance – defines the beam size, its measurement and correction is not only required to optimise the effective available machine aperture thus minimising beam-losses, but also to restore the machine optics symmetry and related feed-down effects (dynamic aperture, resonance driving terms, etc.).

She highlighted that space-charge as another source of beta-beating in SIS100 may link the actual beta-beating working point to the actual beam intensity in the machine.

The measurement and correction depends on the machine model, properly chosen BPMs and powering strategy. Some of the aspects that will need to be investigated are the level of beta-beating to which the machines need to be corrected to (i.e. which level of correction is satisfactory) and whether sorting (and how) of magnets would help to reduce the nominal beta-beating in the first place.

2. Correcting the Beam Optics: Orbit Response Matrix Analysis for the FAIR Storage Rings, O. Kovalenko

Oleksandr explained in his presentations (see slides) how the experimental determination of the linear optics is an essential tool to understand and achieve a high performance of the FAIR accelerators. One of the possible methods to determine the linear optics is using closed orbits (LOCO[1]), which is widely employed to correct linear optics. By default, the orbit (or trajectory) response matrix (ORM) is entered as primary observable into the LOCO algorithm. The ORM is measured as the difference of the orbit (or trajectory) at the available BPMs in response to corrector dipoles, quadrupole and other higher-order magnet excitation currents.

LOCO itself is an iterative process that varies the various corrector (or main) magnet circuit strength within a accelerator lattice design tool (e.g. such as MAD-X) in order to match the

[1] J. Safranek, "Experimental determination of storage ring optics using orbit response measurements", NIM-A 388, 27-36, (1997)

measured ORM measurement (gradient ascent based method). The algorithm is not limited to orbit or trajectories, but is equally applicable and can be complemented by other beam-based measurements such as tune, chromaticity, BPM-to-BPM phase-advance measurements etc.

Oleksandr presented some optics measurements (simulation!) illustrating the LOCO principle using the CR and HESR as an example. In addition to providing information on the optics (beta-function, phase-advance etc.), the algorithm can also provide information on the calibration of the BPMs and CODs, making it a valuable tool particularly for early commissioning to check polarity and gains as well as routine machine operation. Other optics error sources that can be identified are normal and skew quadrupole gradients, sextupole gradients, linear and non-linear coupling, etc.

Next steps are to generalise the prototype software to compatible for all FAIR accelerators (i.e. SIS100), to port the existing code to Java and CSCO controls infrastructure, and to test this with live data at CRYRING, COSY (FZ Jülich), CSR (Lanzhou).

Discussion:

J. Pietraszko for which machine will these be available? R. Steinhagen: all rings and transfer-lines!

D. Ondreka highlighted the difference between identifying local beta-beat error sources and local/global correction of their effects due to the limited number of independent quadrupole families [this is a control theory fundamental: difference between 'observability' and 'controllability']. O. Kovalenko agreed. The achievable beta-beat correction is machine specific and depends on the magnet performance, layout and available corrector circuits.

O. Boine-Frankenheim commented that a student of his had performed similar ORM studies earlier at the SIS18 and highlighted the challenge between 'theory' and applying it to 'real-life' operational conditions. R. Steinhagen agreed and highlighted that this may become critical for the transfer-lines and rings, and for the very same reason that two post-docs (Vera and Oleksandr) are looking into the operational details.

U. Weinrich stressed that already the LOCO-based method should be sufficient for commissioning, provided it requires only one hour. R. Steinhagen agreed that this would be a non-issue for small machines (required time < 1h for SIS18, ESR, CR, CRYRING). However, due to the much larger number of circuits to be check in SIS100 a full LOCO scan would require too much time (about 5h), and one should thus look also into the phase-advance based method since this would be much faster (<0.5 h), provides has a superior resolution and reduced systematics. Due to uncertainties on the magnet hysteresis and beam intensity related effects, it is unclear how often the optics would need to be remeasured/re-validated.

D. Ondreka commented that a precise chromaticity control would be required for the gamma-transition cycle.

R. Steinhagen highlighted that the aim of these developments is to provide an operational tool that – if necessary or required – operators can use routinely to validate and correct the office.

P. Kowina commented on sorting of SIS100 magnets. O. Boine-Frankenheim commented that

Vladimir and Vera are already working on this right now. R. Steinhagen commented that the magnet sorting is independent from the actual beta-beat measurement and correction and outside the scope of FAIR commissioning (→ MPL domain).

S. Reimann asked whether a similar solution would be also envisaged for UNILAC.

General consensus after the meeting was that an operational optics measurement and correction tool is necessary and should be followed-up in due time. Optics measurement and control also in UNILAC would need to be looked into (who?).

The next meeting is planned for: Wednesday 18 May 2016, 15:00-17:00 (SE 1.124c)

Reported by J. Fitzek, S. Reimann, R. J. Steinhagen