PERFORMANCE STUDIES OF AN INTEGRATED ORBIT FEEDBACK SYSTEM WITH SLOW AND FAST CORRECTORS

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Abstract

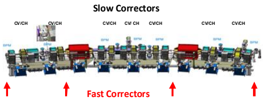
Simulation study and experiments of an integrated orbit feedback system of the combined slow and fast correctors is under way. The slow correctors have the stronger trim strength with slower response while the fast ones have weaker strength but faster response. The integrated system can transfer DC corrections smoothly from fast correctors to slow ones to avoid possible saturation of the fast correctors as well as has an advantage of capability to suppress fast transient orbit drift. This kind of combined slow and fast system has been implemented or planned by several facilities. Taiwan Photon Source is also proposed to apply the scheme in the orbit feedback system design. In this paper, the simulation of the system performance will be presented and its application for TPS will also be discussed.

Introduction

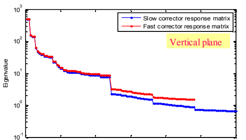
- The lattice of the TPS consists of 24 double-bend cells with 6-fold symmetry, which is designed to achieve a low emittance and a small beam size.
- In the vertical plane, where the beam size is of the order of 5~10 μm, it will be corresponding to have a submicron orbit stability. Therefore, the orbit feedback system is designed to provide such a stable beam.
- To achieve better performance of orbit feedback system, besides the original seven correctors winded on seven sextrupoles, four correctors with faster response are arranged dedicatedly for orbit feedback system in each cell of TPS lattice layout.
- In the following sections, we will study modeling of different subsystem, performance of the integrated orbit feedback system and present a sketch of baseline infrastructure design of the system.

Integrated Orbit Feedback System MODEL with Fast and Slow Corrector

MIMO Model



- TPS lattice layout for each cell.
- FOFB preliminary design :
  - → 5 slow correctors of 7
  - → all of 4 fast correctors
  - → all of 7 BPMs in each cell



- The response matrix R_s and R_f, which relates the orbit shifts to the slow and fast correctors.
- Response matrix could be decomposed by SVD equation :

$$R_f^{+} = V_f \Sigma_f^{+} U_f^{T} \qquad R_s^{+} = V_s \Sigma_s^{+} U_s^{T}$$

- R_s is 168x120 matrix
  R_f is 168x96 matrix

- Max to min eigenvalue
  - →Slow : 725.8
  - →Fast : 328.6

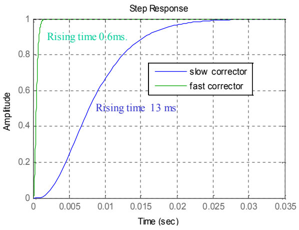
Loop Latency

- Orbit feedback system of TLS :
  Overall loop latency time (620 msec)
  =I/O (500 μsec) + computation (120 μsec)
- Applying the same latency value for the TPS case. In digital model, delay time τ can be approximately 620 μsec sample delay as equation :

$$H_{delay}(z) = z^{-\tau_{delay} \times f_s}$$

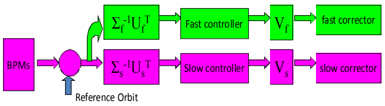
- The sampling frequency f_s is temporarily set to 10 kHz therefore the delay number select the integer 6.

Dynamics Response Model



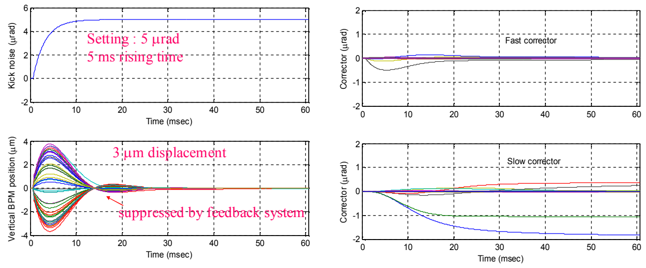
- Overall responses including power supply, magnet and vacuum chamber are approximately a forth order system.

Controller for Slow and Fast Channel

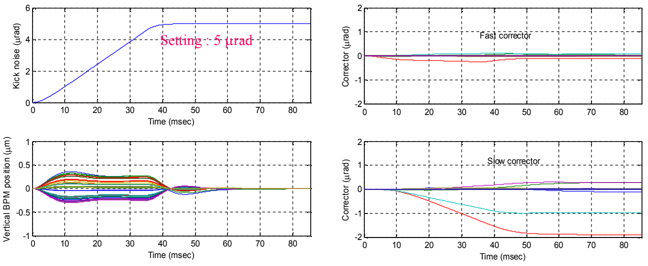


- Two loops with different controller (as the figure shown)
  - → separate the working frequency domain
  - → avoid saturation of fast correctors
  - → avoid counteraction of fast and slow loop
- Orbit data is shared for both loops
- The corrections for both loops are also updated simultaneously.
- There are several controller designs considered and studied.

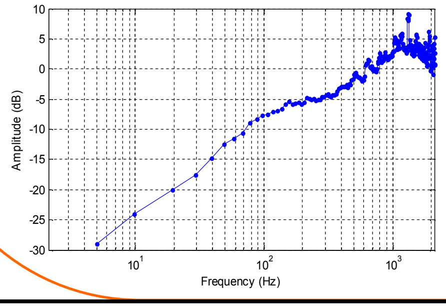
Simulation Results



- Tikhonov regularization is to obtain a stable solution.
- Regularization parameter α is given one fifteenth of maximum of eigenvalue both for R_s and R_f.
- One fast kick has related 5 μrad setting change with around 5 ms rising time and it results the vertical orbit is thus shifted with largest 3 μm displacement and suppressed by feedback system. Orbit deviation vanishes around in 6 ms. It can be observed that at the time 2.5 ms, the correction of fast corrector was gradually transferred to the slow correctors. This demonstrates how the interaction of slow and fast corrections in the two loops.
- From the upper right figures, it is also seen that the corrections of fast correctors to compensate the kick change almost less than ±0.05 μrad at final, which is smaller than correction of slow correctors.

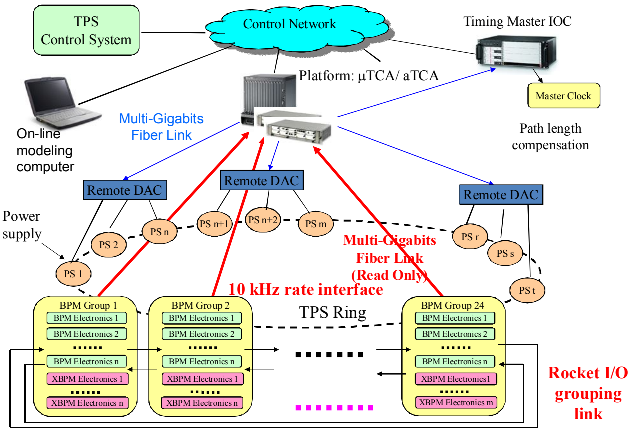


- Another condition is also simulated which anothrt slower kick is applied a continuing change to the same strength 5 μrad.
- As the figure shown, the orbit displace can be less than an fifth compared to the above fast kick.
- The correction of fast correctors gradually decreases at 38 ms when the kicker stops changing.

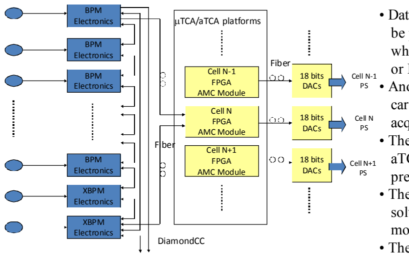


- The bandwidth of the integrated orbit feedback system is initially designed around 500 Hz.
- The more precise number would be evaluated after prototypes of magnets and power supply come out.

Possible Orbit Feedback System Infrastructure



- Several solutions of implementations and platforms are under consideration.
- Advanced Telecom Computing Architecture (aTCA)
  - → High throughput communication and high performance computing capabilities
- MicroTCA (μTCA)
  - → More IO supports as well as advantages of building a distributed system
- Upper figure shows the proposed structure of the integrated orbit feedback system using MicroTCA.
- Libera Brilliance is now the baseline design for the BPM electronics of TPS.



- Data distribution of all BPM values would be processed by FPGA inside Libera, which can be realized by Libera grouping or DLS Communication Controller.
- Another in-house or commercial FPGA card will be used to manage data acquisition and corrector calculation.
- The combination of the low latency aTCA/μTCA with FPGA/AMC will be our preliminary platform.
- The left below figure shows one of possible solution using mTCA with AMC FPGA module.
- The performance of aTCA/μTCA platform running real- time OS Monta Vista is also investigated.

Summary

The integrated orbit feedback system combined with slow and fast correctors of the TPS at the NSRRC is presented in this report. Simulations validate the integrated system fully utilizes the speed of fast correctors and can smoothly pass the strength of correction to slow correctors to avoid saturation of fast correctors. Possible platforms/architectures are also surveyed to implement the integrated feedback system.

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