Orbit Feedback Corrector Requirements for the LCLS

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Software feedback control loops will be used throughout the LCLS for providing fast, single-pulse stabilization of accelerator parameters at rates up to 120 Hz. The list of feedback loops and their requirements is given at
http://www.slac.stanford.edu/~pkr/LCLS/ACBI/fdbk_req.pdf
The beam orbit feedbacks will use magnetic, beamline steering magnets as feedback correctors. The 120 Hz response time requirement for LCLS operation has several consequences for the corrector magnet design, the power supply and the vacuum chamber. These have been determined through refinements in the design of the SLC feedback system, which has similar requirements.
The factors effecting the response time of the correctors are: 1. time constant of the load, determined by the inductance of the magnet; 2. slew rate of the power supply and peak voltage capability; 3. eddy currents in the vacuum chamber and penetration of the field into the beam pipe.

1. Corrector magnet

A standard linac corrector with a pair of dipole windings can be adapted for this application. The coil windings are normally connected in series but by connecting them in parallel the inductance is reduced by a factor 4. The strength of the corrector is also reduced by a factor 2, which reduces the dynamic range of the feedback. This reduction was not a serious problem for SLC operation and should be less of a problem for LCLS operation with less rigid, lower energy beams.

2. Power supply

Two considerations apply to using the standard corrector power supplies in this application. The internal time constant of the supplies needs to be reduced by changing internal capacitors. It would be good to document the changes that were made for SLC and component requirements. The second factor is the peak, transient voltage attainable by the supply in order to achieve fast rise times in the current waveform. The SCOR6 water-cooled corrector chassis used for SLC has a maximum output of 30 V. In general, it is preferable not to exceed 50 V on the grounds that going above this limit would require the additional complication of incorporating new PPS interlocks for electrical safety into the system.

3. Vacuum chamber

When the magnetic field in the corrector changes rapidly there are eddy currents induced in the vacuum chamber which oppose the rising magnetic field. The result is that the desired rapid changes in the magnetic field do not penetrate the beam pipe. The magnitude of the eddy currents and hence the magnetic field attenuation is determined by the resistivity of the vacuum chamber walls. Correctors that were located on copper beam tubes were therefore moved to adjacent sections with stainless steel beam tubes. SLC operation did not require new ceramic beam tubes to be installed in the linac.

Recommendations

SLC experience indicates that the response time of magnetic feedback correctors can meet 120 Hz operation requirements with a few changes. However, the actual details of the changes should be documented by the LCLS design team. The SCOR6 supply does not meet LCLS reliability requirements with its present circuit modifications, so the issue of power supply design requires further review. The measured response of an installed, customized magnetic corrector and power supply should also be documented to show the maximum change in field attainable in $1/120^{th}$ of a second.