SIMULATION AND AUTOMATION OF THE EEBI TEST AT ALS *

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Abstract

The Errant Electron Beam Interlock (EEBI) is a system that protects the vacuum chamber of the Advanced Light Source (ALS) [1] from synchrotron light damage should the orbit, through a superconducting bend magnet (superbend) [2], become distorted. The EEBI system monitors the vertical beam position on two beam position monitors (BPMs), one upstream and the other downstream, of the superbend and dumps the stored beam if the orbit exceeds preset limits in either offset or angle. Discussed are the modelling studies carried out to determine how to create a large vertical bump, both for performing the test and implementing the automated test software.

DESCRIPTION OF EEBI

The ALS storage ring has 12 triple-bend achromat arc sectors. In three of them (sectors 4, 8, 12), the center bend is replaced with a superbend. Fig. 1 shows the optics of the arc of sector 4.

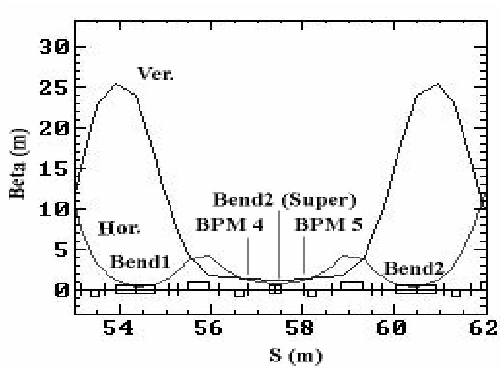

Figure 1: ALS SR Sector 4 Arc.

Two BPMs (4 and 5), one upstream and the other downstream of the superbend and 1.22 m apart, are used to monitor the beam trajectory through the superbend. Although the normal bends are horizontally defocusing gradient magnets, the superbends are pure dipoles. Therefore, neglecting end effects, the vertical trajectory between BPMs 4 and 5 can be considered a drift space, although the complete model is used for simulation studies. The EEBI uses the readout of the vertical beam position on these BPMs to monitor the following conditions.

(1) $|Y4| < 2$ mm and $|Y5| < 2$ mm.
(2) $|Y4 - Y5| < 1.5$ mm.

If one of these conditions is exceeded when the interlock is enabled (beam current >50 mA), The EEBI prevents superbend radiation from damaging the vacuum chamber by causing the main RF to dump the beam.

VERIFICATION OF EEBI

Annual Test

The system functionality is tested annually by setting, in a controlled manner, orbit offset and angle bumps that are greater than the defined limits. Since the interlock does not arm unless the beam current is > 50 mA, the functionality can be verified without dumping the beam by doing the test below the armed, current threshold. Then by slowly setting the perturbed orbit conditions (1) and (2) while monitoring the status of the (disarmed) interlock via data base channels, a precise measure of the orbit is obtained when the interlock opens.

However, creating vertical orbit bumps that exceed the orbit constraints is not trivial due to small values of the beta function.

Case with Nuy = 8.20

When the EEBI was first implemented, the vertical tune of the ring was 8.2; it was for this tune that the EEBI test software was originally developed.

Fig. 2A shows the vertical orbit from sectors 2 to 6 just before the offset of condition (1) breaks. The square dots are the target beam positions at the BPM locations, and the solid line is the measured orbit. The target positions were empirically determined using the linear simulation. In the actual test, the linear model is replaced by the measured response matrix. However, in order to keep the steering magnet settings in a reasonable range, it was not possible to confine the offset bump in a single sector. The resulting bump spans three sectors and makes excursions as large as ±4 mm (Fig. 2A).

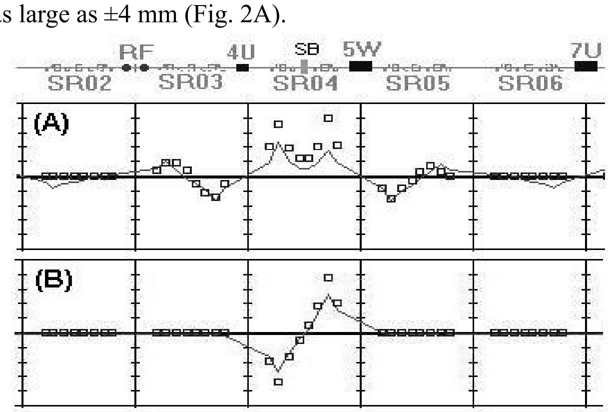

Figure 2: Vertical bumps at sector 4, (A) parallel and (B) angle. Nuy = 8.2, vertical full scale ±10 mm.

Fig. 2B shows the angle bump of condition (2). The angle bump is easier to set than the parallel one and it can be locally confined.

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Case with Nuy = 9.20

Operational considerations made it necessary to change the vertical tune by one unit from, 8.2 to 9.2, to reduce the vertical beam size [3]. Due to the phase change at the higher tune, it was not possible to create the bumps shown in Fig. 2 without setting some of the steering magnets to high current, which in turn introduced hysteresis effects.

The problem became one of determining the shape of a target orbit that does not require extreme settings of corrector magnets. Therefore, instead of using all of the BPMs and steering magnets, subsets of these elements were selected to create the bumps by simulating the process with the model.

Fig. 3 shows the selection of 36 of the 96 available BPMs, and the 46 vertical corrector magnets (VCM) out of 70 that were used for setting the bumps. By using only these BPMs and VCMs, it becomes possible to create parallel and angle bumps for all 3 superbends simultaneously as shown in Fig. 4.

BPM Y	SR01	SR02	SR03	SR04	SR05	SR06	SR07	SR08	SR09	SR10	SR11	SR12
BPM 1	Off	On	On	Off	Off	On	On	Off	Off	On	On	Off
BPM 2	Off	On	Off	Off	Off	On	Off	Off	Off	On	Off	Off
BPM 3	Off	On	Off	Off	Off	On	Off	Off	Off	On	Off	Off
BPM 4	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
BPM 5	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
BPM 6	Off	On	Off	Off	Off	On	Off	Off	Off	On	Off	Off
BPM 7	Off	On	Off	Off	Off	On	Off	Off	Off	On	Off	Off
BPM 8	On	On	Off	Off	On	On	Off	Off	On	On	Off	Off
VCM	SR01	SR02	SR03	SR04	SR05	SR06	SR07	SR08	SR09	SR10	SR11	SR12
VCM1		On	On	On	On	On	On	On	On	On	On	On
VCM2	On	On	On	On	On	On	On	On	On	On	On	On
VCSF1	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
VCSF2	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
VCM3	On	On	On	On	On	On	On	On	On	On	On	On
VCM4	On	On	On	On	On	On	On	On	On	On	On	

Figure 3: Selection of BPM and vertical correctors for setting 3 simultaneous bumps, Nuy=9.20.

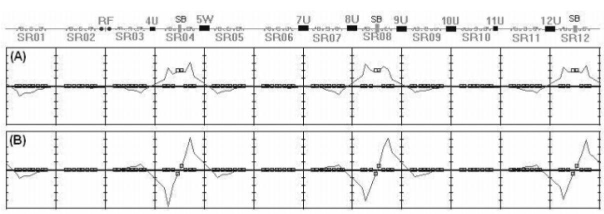

Figure 4: Parallel (A) and angle (B) bumps at 3 superbends, Nuy = 9.2, vertical full scale ±10 mm.

In Fig. 5, the BPMs in the neighbourhood of sector 4 superbend that are not used are in the region marked "Free". This configuration is the same for the angle bumps and for other superbends

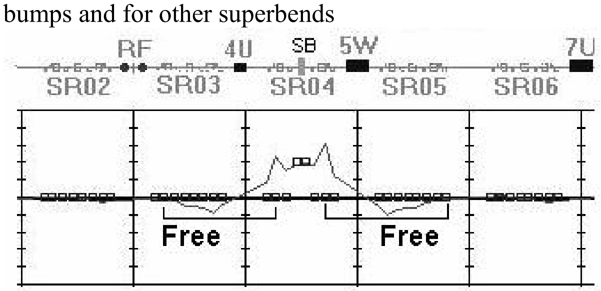

Figure 5: Parallel bump for superbend in sector 4 showing the area where BPMs are not used (marked as Free), Nuy=9.20, vertical full scale ±10 mm.

This method of setting the three offset or angle bumps simultaneously gives an efficient and reproducible way of performing the EEBI test. A computer program (Fig. 6) was created to automate the process.

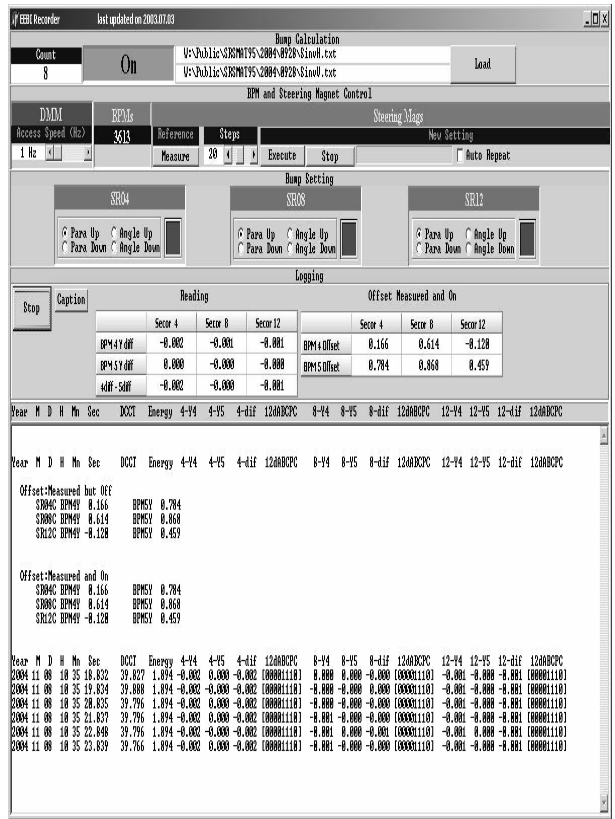

Figure 6: A program that automates the annual EEBI test.

AKNOWLEDGEMENTS

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