AN IMPROVED CLOSED ORBIT SERVO FOR ENERGY RAMPS ON THE SRS AT DARESBURY

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Abstract

The SRS is a second generation synchrotron radiation source which ramps from its injection energy of 600 MeV to 2 GeV relatively slowly (~ 1 minute). Improvements in orbit control have been achieved using discrete corrector application at specific points during the ramp, but this requires regular dedicated beam studies time to re-optimise the stored steering files to match the gradual uncorrected orbit degradation with time. The installation of two new Insertion Devices (IDs) in the ring, with their consequent much reduced vertical aperture specifications, will demand a higher degree of position control and unacceptable use of resources. A ramp orbit control servo program has been commissioned and is in operational use in the normal (multibunch) mode ramp, operating with a loop time of 2 seconds. Results from this, together with a modification to allow the handling of specific conditions used in a relaxed emittance mode (for single bunch filling), are shown. Since the servo must be "fail-safe" to avoid irradiation of the new ID vessels, methods to handle BPM failures are discussed.

1 INTRODUCTION

The Daresbury SRS is a second generation light source and the world’s first high energy dedicated synchrotron radiation source. Beam is ramped from an injection energy of 600 MeV to a final energy of 2 GeV over a period of approximately 1 minute. This mature source now delivers beam into a large number of user stations for ~ 6000 hours/year, the majority of which is gapped-multibunch at the standard (HIQ) tunepoint of (Q_r, Q_v = 6.21, 3.37). Typically 10 % of scheduled time is devoted to a single-bunch mode (30 mA) which utilises a relaxed emittance setting (LOQ: Q_r, Q_v = 4.21, 3.23) to reduce a Touschek limitation on lifetime.

1.1 Requirement for Orbit Control

It has been necessary for some number of years to apply closed orbit correction, in order to reliably ramp high currents over periods of several months of bare orbit degradation [1]. This orbit control used the application of previously acquired discrete corrector files to maintain orbit deviations of < 3.5 mm horizontally and < 1.6 mm vertically, at the expense of periodic dedicated beam studies periods, where paused ramps were required to correct the orbit and save corrector settings to file. The installation of reduced aperture vessels into the SRS lattice [2] now means that orbit control requirements are tighter than previously allowed, so a fast orbit feedback servo system has been developed to control beam position during the ramping phase and is now in operational use.

2 ORBIT MEASUREMENT AND CORRECTION

The SRS has a 16 cell FODO lattice structure, with a circumference of 96 m. Each straight contains one electron beam position monitor (BPM) and two sets of corrector elements per plane.

2.1 Control of BPM & Corrector Elements

The available correctors are more fully described elsewhere [1] but can be summarised as one set of dedicated correctors (vertical steering magnets (VSTMs) for the vertical plane and trim windings on the main dipoles (DIPTs) for the horizontal plane), together with a multipole magnet where combinations of windings (12 in total) can be used to give vertical correction (VSTR), horizontal correction (HSTR) and octupole field (OCTP).

All corrector elements and standard BPMs are controlled by a VME distributed system running the OS-9 real-time operating system. Downconversion of the detected 500 MHz component from the BPM buttons and subsequent measurement is performed using 16 distributed BPM processor/ADCs, with data collected from paralleled units by intermediate processors using G64 architecture and also running OS-9 [3]. The multistage acquisition of BPM data with several processes running asynchronously gives a summed worst case delay/update of approximately 1.2 seconds.

2.2 Injection Requirements

Injection takes place into a corrected orbit. VSTMs are used in both tune modes to correct the vertical orbit during all beam stages prior to beamline steering at 2 GeV. In HIQ, the horizontal plane DIPTs are sufficiently strong to provide correction, with a large static bump at the injection septum provided by the controlled shunting of current from the dipoles surrounding the injection straight (the DSHN-Bump).

The LOQ injection regime in the horizontal plane is similar, with a large DSHN-Bump required to bump the beam outwards to the injection septum in Straight 1, but with a second large negative (inwards) bump required at Straight 2 also. This has been necessary for injection for some years and is provided for by a 3-magnet HSTR bump.

3 RAMP SERVO AND HORIZONTAL ISSUES

A ramp servo control program (RSERVO) has been written in 'C' to run under OS-9 on the main Steering System VME processor. It presently uses a simple 16x16 matrix inversion correction algorithm and is based on the successful global orbit servo that has been in use for four years to maintain the horizontal user orbit during a fill [4]. A second output from a DCCT on the main dipole circuit as measured by a 16-Bit ADC in the VME Steering System is calibrated to provide energy scaling of the corrector strength required. A plain text configuration file is used to specify required correction methods and options. Empirically derived square response matrices are used for the three corrector families employed for orbit correction during the ramp.

3.1 Basic Servo System

The program can be configured to provide servoing in the horizontal or vertical planes or both. For each plane, the orbit is measured from the 16 BPMs, a correction predicted and applied onto the existing corrector values. A configurable delay is then set before the next orbit read is performed. Provision to trip to test-mode (no application of correctors) is provided for if any corrector would be set beyond its saturation threshold.

3.2 Horizontal Correction in HIQ

The SRS hybrid control system does not allow control of the DSHN-Bump elements by the ramp servo, so allowance for the energy-dependent effect of the bump is made after measuring the orbit. At low energy the bump takes the ideal closed orbit to approximately 11 mm, beyond the linear region of the BPM response. To measure the displacement at this BPM, the servo uses a non-linear fit to measured response data [3]. An energy dependent offset is then subtracted to take account of the effect of the DSHN-Bump at HBPM1. Figure 1 shows the DSHN-Bump ON-OFF data taken from a paused ramp, plotted inversely against energy. The linear fit shown has proved accurate enough to correctly handle the reduction in the orbit offset associated with the bump during the energy ramp. A similar method is used to provide an offset for the residual effect of the DSHN-Bump at HBPM2, although its effect is much smaller (~ 4 mm at injection).

DIPT correction is used at low energy, but the power supply saturates during the energy ramp (typically at 1 GeV). The servo checks for imminent saturation and automatically swaps to HSTR correction from then on, leaving the residual DIPTs applied.

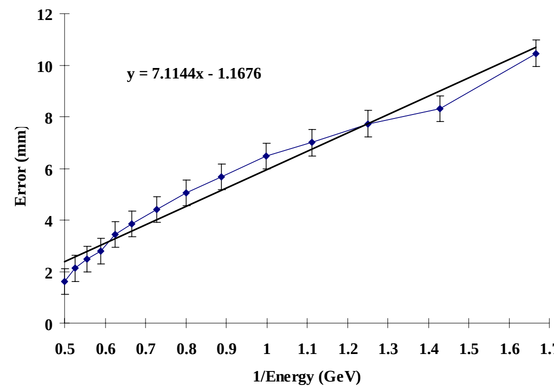

Figure 1: HIQ Orbit Error Calculation for DSHN-Bump.

3.3 Horizontal Correction in LOQ

The large positive offset at HBPM1 due to the DSHN-Bump is handled in the same way as in HIQ. Handling the large negative bump at HBPM2 is more complex, since the bump is to be rolled-off to zero slowly during the early part of the ramp but at some intermediate energy the residual offset due to the effect of the DSHN-Bump must be allowed for in the same manner as HIQ.

The method presently used in the LOQ ramp servo is to specify HSTR-only correction throughout the ramp and programme the error due to the required Straight 2 injection bump through a datafile, read-in at initialisation time. At 1.125 GeV a swap is made to a fit to the residual error at HBPM2 due to the DSHN-Bump, as in HIQ. Figure 2 illustrates the present offset handling in use.

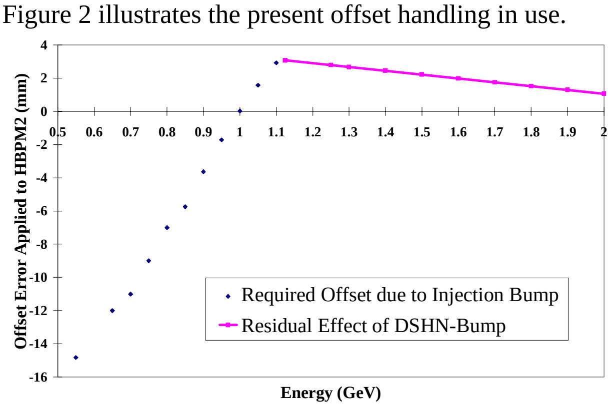

Figure 2: Offset (Error) data used for HBPM2 handling in LOQ.

The use of HSTR correctors means that the required injection bump and its roll-off are correctly produced.

3.4 Ramp Servo Ancillary Tasks

Other procedures have been added to the basic servo to allow integration into the standard refill procedure:-

1. Roll-off of all DIPTs to zero at 2 GeV, over several steps whilst re-correcting on HSTRs.

2. Removal of DSHN-Bump handling at 2 GeV, prior to the manual removal of the bump itself.
3. Automatic adjustment of the programmed octupole field during the ramp, to avoid the possibility of multipole winding saturation when correcting using HSTRs. Roll-Off to zero of OCTP field at 2 GeV.
4. Programmable removal of average horizontal corrector offsets.
5. Full data logfile generation.
6. Integration with the SRS operator PC-based interface system to allow control of the servo and status reporting.

Items 1 to 4 allow the use of the ramp servo to provide orbit control during the ramping to full field of the two superconducting wiggler magnets, to compensate for minor tracking errors in the trim windings.

4 PERFORMANCE OF THE RAMP SERVO

Figures 3 and 4 show the typical performance of the ramp servo during beam stacking, energy ramping and wiggler ramping phases in HIQ.

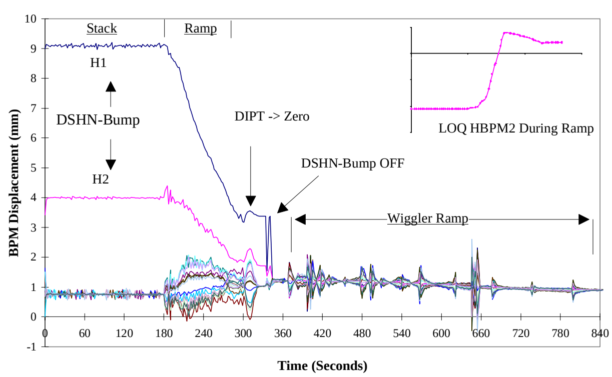

Figure 3: Horizontal Orbit Control During Stacking and Ramping in HIQ

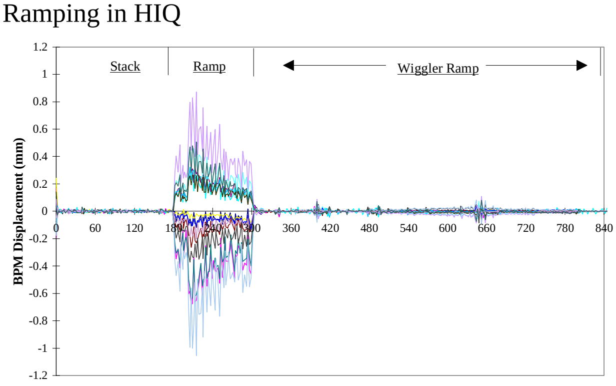

Figure 4: Vertical Orbit Control During Stacking and Ramping in HIQ

LOQ performance is similar, with HBPM2 (shown in inset) following closely the required profile. Good orbit control is maintained throughout with maximum deviations at least a factor of 2 below that achieved previously (maximum r.m.s. figures in both planes of << 1 mm typical (outside of injection bumps in the horizontal plane)). Since the BPM update rate limits the minimum loop time, some optimisation has been possible by increasing the ramp time to 2 minutes (allowing more servo loops in the ramp).

5 RESILIENCE TO BPM ERRORS

The ramp servo is not BPM fault tolerant due to the simple correction technique employed: any BPM fault renders the program unusable in that plane. Though generally reliable, methods are required to handle BPM/ data-acquisition system fault conditions, to allow continued beam operations until the fault can be rectified. The long term solution is to replace the simple corrector technique by the far more powerful SVD system, to allow the possibility of ignoring specified BPMs and still allowing orbit correction.

The immediate solution has been to develop an open-loop version of the ramp servo: RAMPSTEER. This uses RSERVO logfile data, specifying sets of DIPT, HSTR, OCTP and VSTM correctors to maintain a corrected orbit at a given energy. This recreates the original method of orbit correction (as described in [1]), with the advantage that the data is obtained parasitically, so that no intensive beam studies time is required. The program has also been written to run at the VME Steering System level, giving it a speed increase and robustness that the former discrete corrector application method cannot match. The system has been tested in both HIQ & LOQ and is operational for use during the energy ramp.

6 SUMMARY

A ramp servo system and it’s open-loop variant have been successfully implemented in HIQ and LOQ modes on the SRS. With the installation of the reduced aperture MPW vessels, their use is now very important to keep beam during ramping.

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