DARESBURY SRS POSITIONAL FEEDBACK SYSTEMS

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Abstract

The Daresbury SRS is a second generation synchrotron radiation source which ramps from its injection energy of 600 MeV to 2.0 GeV. Beam orbit feedback systems have been in routine operation on the SRS since 1994 and are now an essential element in delivering stable photon beams to experimental stations. The most recent enhancements to these systems have included the introduction of a ramp servo system to provide the orbit control demanded by the installation of two new narrow gap insertion device and development of the vertical orbit feedback system to cope with an increasing number of photon beamlines. This paper summaries the current status of these systems and briefly discusses proposed developments.

1 INTRODUCTION

Orbit position control has been employed at Daresbury to stabilise the photon beam position routinely since 1994. The global horizontal feedback system [1] has been in routine operation for many years and uses a simple inversion of the 16 x 16 response matrix to apply a correction every 30 sec. A global vertical orbit feedback [2] has now replaced the individual local servo systems [3] that pioneered vertical orbit correction for beamlines on the SRS. This global vertical system provides orbit control using tungsten vane monitors (TVMs) at all commissioned ports and will allow expansion of correction to new beamlines including two new multipole wiggler (MPW) sources. A consequence of the introduction of these MPWs and their associated small aperture vessels was an increased requirement for orbit control during the energy ramp. This has been provided by a flexible, automatic orbit control program [4], which runs a dual plane global feedback system using the electron beam position monitors (BPMs).

2 HORIZONTAL GLOBAL FEEDBACK

The global horizontal feedback system reads the horizontal electron orbit at 16 BPMs and applies a global correction at the 16 steering magnets (HSTRs), the strength of the correction is determined by a straight inversion of the steering magnet response matrix. The orbit is read and a correction is applied every 30 sec. This system has been in used on the SRS for many years and considerable experience has been gained. The system has been highly successful in suppressing the orbit shape distortions, although the average radius change is not corrected. This is because the machine orbit is relatively insensitive to changes in the average position of quadrupole magnets and as a result correction of this orbit component is vulnerable to systematic movements in the BPMs. The global horizontal feedback system corrects all the BPMs to the average of the 16 BPMs, within a precision of the order of the BPM resolution (better than 5 μm). The latest work on this system has concentrated on dealing with the malfunction of an individual BPM. Clearly with only 15 monitors and 16 correctors a simple matrix inversion is no longer applicable, however it has been shown that an SVD algorithm provides a good solution to the missing BPM problem and work is currently underway to integrate this algorithm and the detection of BPM problems into the global feedback system.

3 VERTICAL GLOBAL FEEDBACK

Currently the global servo system includes TVMs on dipoles 1,2,3,4,6,7,8 and 13, super-conducting wigglers in straights 9 and 16 and an undulator in straight 5. Each port has one TVM except super-conducting wiggler, W16, which has two TVMs at different distances from the source however, the beam is only steered to one of these two monitors. TVMs were fitted as close as possible to the typical experiment distance but this can be anything from 3 - 15 m. So the vertical global feedback in the SRS could potentially use 11 photon monitors and 16 vertical BPMs, with correction supplied by up to 2 x 16 vertical correctors.

An EXCEL program was used as a flexible development environment. This program was designed to provide on-line correction and servo feedback of the orbit together with off-line simulation.. A singular value decomposition, SVD, routine was used to “invert” the appropriate measured orbit response matrix of the corrector magnets at the chosen monitors.

The photon monitors were used for feedback because of problems with the position stability of the vertical BPMs due to thermally induced movements of the vessels. Simulations and beam tests were carried out using 32 and 16 vertical correctors. It was determined that the use of only one family of 16 correctors was adequate to correct the orbit at one TVM on each of the 11 ports.

A simplified version of the correction program has been used for operations. The system has been designed to deal with the slow drift in orbit due to thermal effects in the machine that can be several 100 microns over a stored beam of up to 23 hours duration. Although it would be possible to run at around 2 second update, a correction every 30 sec has been chosen, as this matched the performance achieved at only few ports using the previous local correction system. At this update rate, even at the start of a fill when the drift is fastest, the applied correctors are only a few LSBs.

Figure 1 shows the results achieved using this global feedback system during a user beam. The data illustrates that the system operates with a correction accuracy of around a few µm on all the corrected TVMs. This is probably the limit of achievable accuracy as the expected RMS error due to setting errors on the 16 magnets is 1.5 µm and the resolution of the TVMs is around 1 µm. For comparison, Figure 2 shows a prediction of the drifts that would have occurred during the same period without the feedback on.

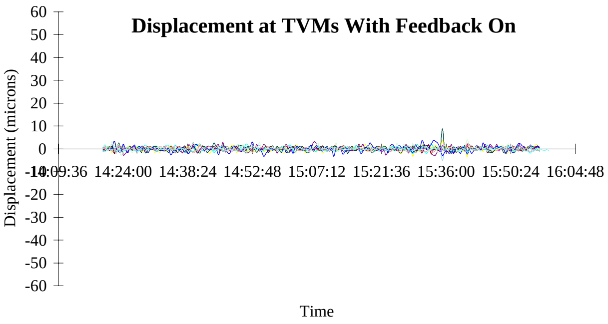

Figure 1: Operation of global vertical.

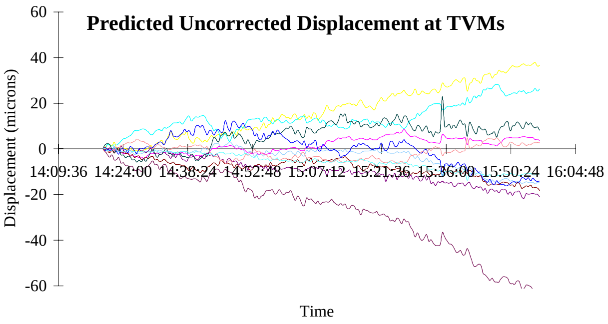

Figure 2: Predicted drift at TVMs without feedback

The system had to be designed to load a new response matrix if a port was shut and the associated photon monitor no longer available or a monitor failed in some manner.

The SRS is still expanding the number of operational beam ports, the most recent addition was a new port on dipole 5. This is in a particularly densely populated region of the ring as there is an undulator in straight 5 and dipole sources on adjacent dipoles.

The response matrix was extended to include the measured response at the new TVM and the off-line simulator was used to assess the predicted correction with the additional TVM present. The decomposition immediately highlighted that the present operational arrangement for correction using only the 16 VSTM magnets would have problems. However, the addition of just one corrector (VSTR.05) in this region gave a far more "stable" system. The simulation predicted much more effective correctors for full orbit correction. These solutions were investigated using the simulator. The corrector strengths required to correct 100 different random orbits that were recorded with and without correction at the new TVM. The results are shown in Figure 3. These show clearly that the 16 magnet solution would require the use of very strong correctors. This would be impractical, as the increased sensitivity to realistic errors in response would produce unacceptable errors.

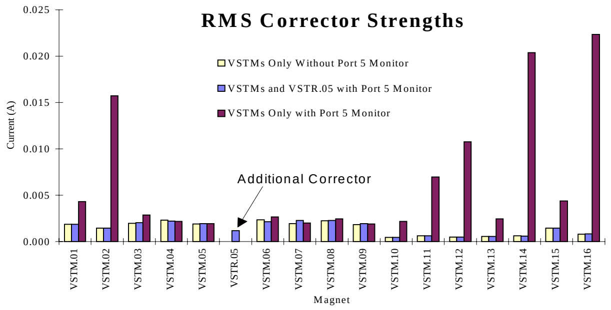

Figure 3: RMS corrector strengths required to correct the orbit at the TVMs with and without dipole 5 TVM.

Testing with beam of combined VSTM and VSTR correction will take place shortly when the port is fully commissioned and available during beam studies. Further expansion of the system is planned later in 1999 with the addition of two new multipole wigglers in straights 6 and 14.

4 RAMP ORBIT FEEDBACK

Survey errors and "magnet walks" in the SRS mean that without orbit control deviations of over 10 mm can develop in some areas during the energy ramp from 0.6 to 2.0 GeV. The orbit feedback system that operates in both planes has been designed to control these orbit excursions and meet the stringent demands due to the installation of relatively small gap MPW vessels.

The SRS has is a 16 cell FODO lattice with one vertical and one horizontal BPM per cell. The corrector and monitor layout is shown in Figure 4.

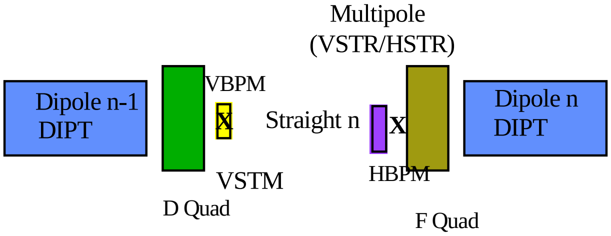

Figure 4: Correctors and monitors in an SRS lattice cell

The vertical steering magnets, VSTMs, are dedicated vertical corrector magnets, The multipole magnet has 12 windings which can be individually programmed for horizontal deflection (HSTR), vertical deflection (VSTR) and octupole field. Each dipole has a trim coil (DIPT) for horizontal correction.

The energy ramp feedback system is based on an extension of the simple matrix inversion technique, used for horizontal global feedback, to both planes. Vertical orbit correction is made using the 16 dedicated vertical steering magnets (VSTMs) and the 16 vertical BPMs. The horizontal correction involves the use of both sets of horizontal correctors. At low energy the multipole is required to provide a strong stabilising octupole field and the horizontal correction is applied using the relatively weak dipole trim coils. At higher energy, the feedback program dynamically swaps to provide correction using the HSTR configuration of the programmed multipole and tailors the octupole component on the multipole to avoid winding saturation.

Injection is achieved in the SRS with a large, ~ 11 mm bump. This bump takes the ideal closed orbit beyond the linear region of the BPM response. A non-linear fit to measured BPM response data is used by the feedback program to ensure accurate correction in this region.

This feedback system is required to maintain control during the relatively fast energy ramp of ~ 70 sec, the maximum correction frequency is limited to 1.4 sec due to the various delays involved in the acquisition of through a hybrid of several computer systems.

Figures 5 and 6 show the typical performance of the ramp servo during beam stacking, energy ramping and wiggler ramping phases.

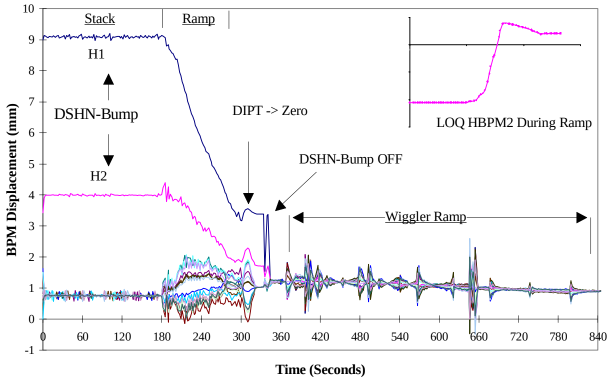

Figure 5: Horizontal Orbit Control During Stacking and Ramping.

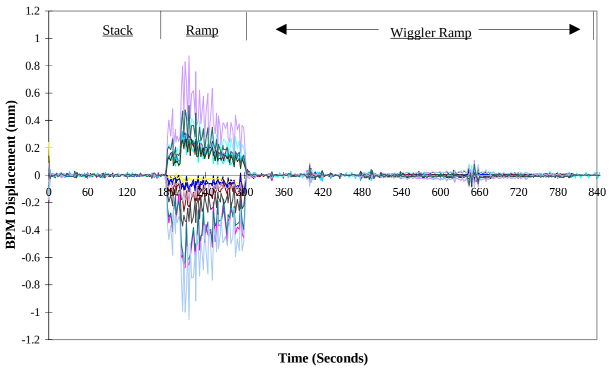

Figure 6: Vertical Orbit Control During Stacking and Ramping.

5 SUMMARY AND OUTLOOK

The horizontal global feedback system has operated very successfully to reduce the closed orbit ripple for many years. Developments are now centred on the introduction of a new SVD system to allow continued operation in the presence of a monitor or magnet failure.

The global vertical orbit feedback system has been developed to meet the demands of an increased number of beamlines in the SRS. It has been demonstrated to be highly effective at providing stable photon beam. This system provides beams, stable to the micron level, at a monitor in a beamline on each port in the SRS. The facility will be extended to cope with the proposed new beamlines.

The extension of global feedback on the electron beam monitors to both planes for operation during the energy ramp has provided the necessary orbit control to cope with reduced aperture vessels due to the installation of the new MPWs.

REFERENCES

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