Development of Global Feedback for Beam Position Control in the Daresbury SRS Storage Ring

B.G. Martlew, R.J. Smith, S.L. Smith
DRAL, Daresbury Laboratory, Daresbury, Warrington WA4 4AD, UK

Abstract

A global feedback system designed to correct and control the closed orbit position drifts in the SRS storage ring with high resolution is described. The theoretical performance of such a system has been analysed, based on the known capabilities of the recently upgraded electron beam steering and monitoring systems. Experimental results showing the achieved correction of horizontal orbit around the ring are also presented.

1. INTRODUCTION

The Daresbury SRS is a second-generation light source based on a 2 GeV electron storage ring. It has been in operation since 1981 and a major upgrade of the lattice to a high brightness design took place in 1987[1]. Beam position stability has become of vital importance to the successful exploitation of the SRS during the past few years and a major program of development in all areas of beam stability has been undertaken at Daresbury. This paper deals with the systems that have been developed for global orbit feedback and the results from early trials.

2. BEAM POSITION STABILITY ON THE SRS

Extensive measurements have been made of the position drift of both the electron and photon beams in order to characterise the problem and to try to identify the cause of the beam movement. These measurements and the conclusions reached have been clearly described by P.D.Quinn et al[2]. Briefly, the important points are:

1. High frequency vibrations (> 1 Hz) are at a relatively low level and do not present a major problem on the SRS.
2. Over a period of several months errors occur in the lattice alignment due, in part, to the repeated thermal cycling of the storage ring. Regular measurements and occasional quadrupole re-alignments are necessary to correct this problem[3].
3. The drift in beam position during a single fill of the storage ring (typically, 24 hours) is particularly troublesome to users. Electron beam position movements of ± 100 μm during the first few hours of a fill are quite usual. It is hoped to reduce this drift by a combination of techniques; global feedback to maintain a constant horizontal closed orbit and local feedback of the vertical beam position on individual beamlines[4].

3. HARDWARE AND SOFTWARE DEVELOPMENT

3.1. *Steering control system*

In 1993 large-scale improvements were made to the steering magnet control system. Previously, all the corrector magnets had been controlled and monitored by old, 12-bit digital-to-analogue and analogue-to-digital converters (DACs and ADCs). The new system is based on a network of VMEbus crates with 16-bit DACs and ADCs that have been carefully selected for best noise and stability performance. More precise control of orbit position, increased system flexibility and extra computing power for complex feedback algorithms are the main advantages gained from the new system[5].

3.2. *Electron beam position monitors*

The SRS is equipped with 16 horizontal and 16 vertical electron beam position monitor (BPM) vessels, fitted in pairs in the machine straights. All monitors use capacitive button type pickups to sense beam position. The signals from these pickups are pre-processed via adjacent passive 180° hybrids, to give sum (Σ) and difference (Δ) signals which are detected and processed. The use of hybrids ensures a wide band linear response and allows beam current independent position to be found. These Σ and Δ signals, once processed, provide a stable measurement of beam offset about the reference beam orbit.

A major upgrade of the system in response to requirements for improved orbit control has meant the design and implementation of new distributed processing electronics. Based on a down conversion technique, signals are passed from the hybrids, directly into new two channel processing units, mounted with the BPM vessels. These 500MHz input signals are mixed down to 500kHz, whilst retaining all the input amplitude components. An incorporated low frequency processing stage then produces filtered DC outputs which are passed directly into the individual, directly coupled ADCs for digitisation. This technique has given an overall factor of 10 improvement in measurement precision, to give position over a wide dynamic range of beam current (>26dB) to an accuracy of ±5μm and a repeatability of measurement approaching 1μm. The processor units were designed completely in house, at modest cost, and can cater for other basic BPM operations including first turn injection and tune measurement. The down conversion technique also makes them versatile for fitting to future machines with different operating frequencies[6,7].

3.3. Global Feedback Software

Special software has been designed and written for global feedback control. It is based on an interactive, closed-orbit correction program, CORRECT, that has been in use on the SRS for many years and utilises the least-squares method of orbit correction. Simply, the software reads the orbit from the 16 electron BPMs, calculates the required corrector strengths, applies the calculated correctors and then repeats the whole cycle after a pre-determined delay (typically, 30 seconds). Operation of the software can be customised by a configuration file that specifies, among other things, the feedback update rate, the name of a file containing the lattice response matrix and corrector calibration factors. The software also allows for automatic collection of orbit data for later analysis [4].

4. COMPUTER SIMULATION OF ORBIT CORRECTION

Due to the lack of horizontal photon monitors on the SRS beamlines it is impossible to make quantitative on-line measurements of the horizontal orbit position and angle at the beamlines. To allow simulation of the global horizontal feedback system and to assess the effectiveness of the applied correction at the beamlines, the program CORRECT was incorporated into the in-house Daresbury lattice code ORBIT [8].

The program's closed orbit options allowed the simulation of the orbit distortions due to random errors in position of the two families of 16 quadrupoles in the SRS lattice and the correction of the resultant closed orbit as measured at the 16 electron BPMs. The program also has the facility to calculate the effect on the correction of a random error at each of the BPMs.

A simulation was made of the correction of the horizontal orbit drift by considering five different orbits due to different sets of random errors in the quadrupole positions. The errors were set to give an average RMS orbit displacement of approximately 50 μm at the electron BPMs, a value typical of drifts measured in the SRS over a few hours of beam. The results indicated that, at the centre of the dipole where the random quadrupole errors had resulted in an average RMS error of approximately 32 μm in position and 17 μrad, correction using the 16 horizontal steering magnets achieved an average RMS of 1 μm in displacement and 0.5 μrad in angle. This result assumed zero error in the BPM readings. Including typically measured random BPM errors with a standard deviation of 5 μm, the correction now achieved average RMS orbit errors at the centre of the dipole of 3.6 μm and 1.4 μrad respectively.

5. EXPERIMENTAL RESULTS

During the Spring of 1994 several experimental runs of global, horizontal feedback have been possible. Measurements have been made of the ability of the system to correct both artificially produced orbit distortions and the natural, thermally induced position drift. Although initial plans called only for global, horizontal feedback it has also been possible to test the effectiveness of the system in the vertical plane.

Figures 1 and 2 show the uncorrected drift of the horizontal closed orbit during typical operating conditions (2 GeV, 300 mA circulating beam and 27 hour lifetime) immediately following a refill. The maximum drift can be seen to be approximately ±100μm.

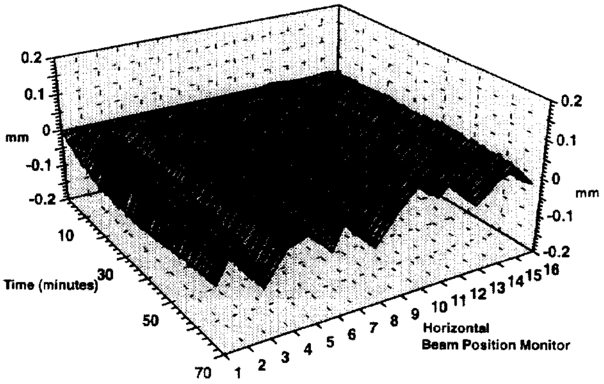

Figure 1. Horizontal orbit drift without feedback

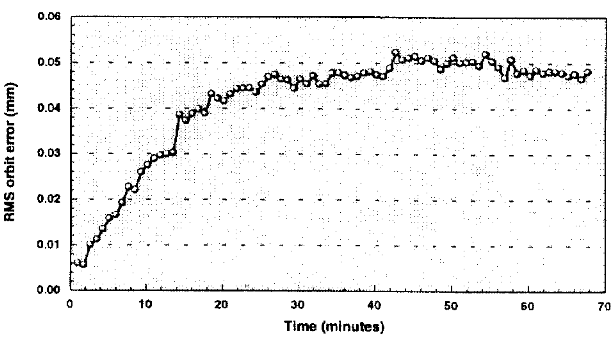

Figure 2. RMS orbit error - Feedback off

Figures 3 and 4 show a beam under identical conditions but with the global feedback system in operation. The improvement in beam stability is obvious. The maximum error is now < ±20μm and the RMS error remains constant between 2.5 and 5μm. It is interesting to note that a small amount of noise can be seen on beam position monitor 4. This is caused by pick-up of external, electrical noise and is not a true beam effect.

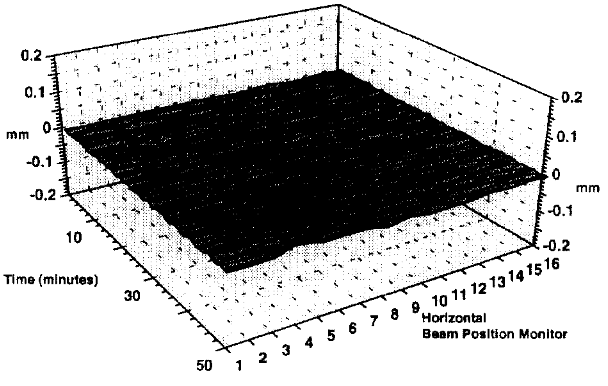

Figure 3. Horizontal orbit drift with feedback operating

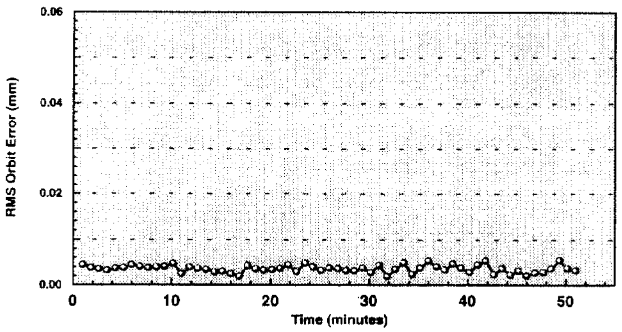

Figure 4. RMS orbit error - Feedback on

The response of the feedback system to an artificially induced, periodic orbit distortion is shown in Figures 5 and 6. For this experiment a triangular oscillation was induced onto the beam initally with feedback switched off, then, after 1 or 2 cycles of the oscillation, the feedback system was switched on. The amplitude of the residual beam movement is proportional to the feedback update rate.

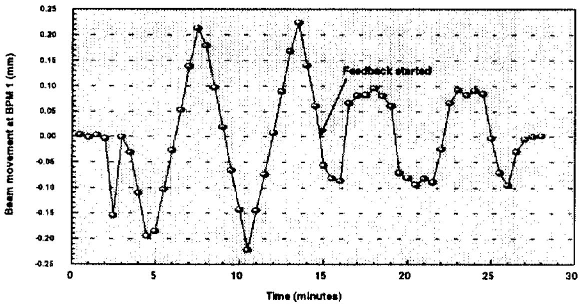

Figure 5. Induced orbit oscillation (30 sec feedback)

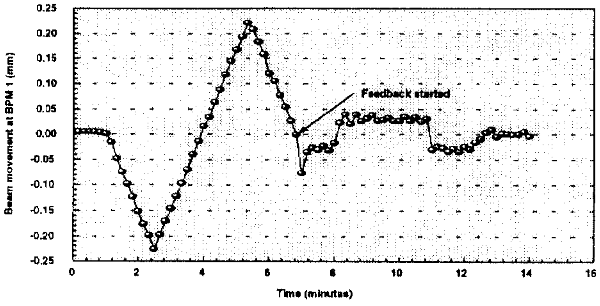

Figure 6. Induced orbit oscillation (10 sec feedback)

Similar experiments have also been performed on the vertical orbit. The results obtained are very similar in all respects to those described above for the horizontal orbit.

In June 1994 an 8 hour trial of global, horizontal feedback was undertaken to enable beamline users to judge the effect of the system on individual beamlines and experimental stations. All the results from this trial are not yet available but early reports show that a clear improvement in horizontal beam stability was noted.

6. CONCLUSIONS

The results obtained so far have been extremely encouraging. The feedback system has demonstrated its ability to reduce the orbit RMS from 50 μm to 5 μm over the period of a fill of the storage ring. However, further work remains to be done to optimise the system and to add various 'safety traps' to the software before global feedback can be considered ready for routine operational use. Investigations will also need to be undertaken into the interaction between global, vertical and local, vertical feedback before routine use of global, vertical feedback can take place.

7. REFERENCES

[1] V.P.Suller, et al, "SRS-2: Performance and Achievements", Proceedings of Particle Accelerator Conference, Chicago, March 1989. pp 467-469

[2] P.D.Quinn, J.N.Corlett, M.W.Poole, S.L.Thomson, "Beam Position Stability in the SRS at Daresbury", Proceedings of the European Particle Accelerator Conference, Nice, June 1990. pp 134-136

[3] L.A.Welboune, "Long Term Drifts and Corrections of the SRS Closed Orbit", these proceedings.

[4] J.A.Clarke, E.A.Hughes, B.G.Martlew, M.W.Poole, P.D.Quinn, S.L.Smith, V.P.Suller, L.A.Welbourne, "High Resolution Stabilisation of the Vertical Position of Photon Beams in the SRS Beam Lines", these proceedings.

[5] W.R.Rawlinson, B.G.Martlew, M.J.Pugh, M.McCarthy, "Development of a VME-Based Control System for the SRS Orbit Feedback Project", these proceedings.

[6] R.J.Smith, P.A.McIntosh, T.Ring, "The Implementation of a Down Conversion Orbit Measurement Technique on the Daresbury SRS", these proceedings.

[7] L.M.Ford, M.T.Heron, R.J.Smith, "A High Precision Digitiser and Multiplexer for the New Orbit Processing Electronics at Daresbury", these proceedings.

[8] S.L.Smith, "MAC Orbit", Daresbury Laboratory internal note, 21 December 1993.