Long Term Drifts and Correction of the SRS Closed Orbit

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Abstract

A study has been made of changes to the uncorrected (bare) beam orbit in the SRS. Over a period of many months a deterioration in the orbit is seen which can be correlated to progressive physical movement of the lattice quadrupole magnets. An on-line correction program is available to flatten the orbit, using one or both of two types of corrector in each plane. This can also predict optimum magnet moves to improve the bare orbit. Results are always checked by on-line simulations before moves, which are needed at approximately annual intervals. Results of a number of moves are reported, with some comments on the degree of success achieved.

1. INTRODUCTION

Deterioration of the horizontal bare orbit over long periods is seen to occur in the SRS. An example of the orbit deterioration over a six month period is presented here. The subsequent requirement for ever-increasing corrector strengths necessitates correction of the orbit by quadrupole re-alignment at approximately annual intervals. Effective moves of combinations of the 16 F-Quadrupoles in the SRS FODO lattice are predicted off line using measured and predicted orbit data. Results are simulated with beam prior to magnet moves so that any differences can be resolved.

2. BARE ORBIT MEASUREMENT

Orbit measurement is carried out using beam position indicators in each of the 16 cells of the SRS. The system used is described more extensively elsewhere [1]. At large orbit displacements, greater than say 10mm, saturation of the BPM system is known to occur, leading to non-linear response. While it is generally possible to store a beam under bare orbit conditions, in order to avoid inaccuracies in measurements of poor orbits a technique of applying fractional bare orbits has been adopted. Corrector strengths for flat orbit are recorded, then a percentage of these applied, leaving the remaining percentage bare orbit.

Bare orbits can also be calculated using known correctors for flat orbit and the measured machine response matrix. This method must be used with care to ensure machine conditions, especially tune, are specified accurately, or large errors can be introduced. The advantage of using an empirical rather than computed response matrix is that it reflects the variability of lattice functions known to exist in the real machine [2].

3. BPM NON-LINEARITY

Differences in the full and scaled fractional bare orbits give an indication of the point at which BPM non-linearity must be taken into account. This in turn allows a mechanism by which data recorded with large orbit offsets in the past can be adjusted to compensate for possible saturation effects. Differences in the 1/4 scaled and full bare orbit showing the deviation from linear response is shown in figure 1.

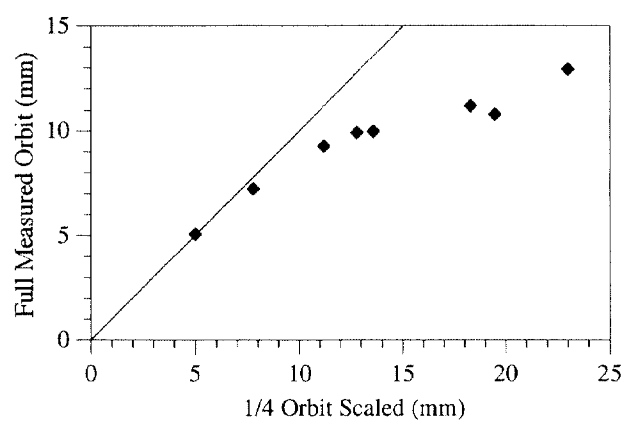

Fig1. Measured and actual orbit deviations.

It can be seen that for orbit displacement greater than 6-7mm the BPM response moves into a non-linear region. Application of fractional bare orbits which keep the electron beam displacement below this level, and applying a suitable scaling factor helps eliminate errors caused by this non-linear response.

4. LONG TERM ORBIT DRIFTS

The bare orbit in the SRS is measured on a regular basis and changes over extended periods monitored. Figure 2. shows changes in the bare orbit as recorded between 21/6/93 and 8/1/94. The RMS orbit displacement increased almost linearly from 5.3 to 11.4mm during this period.

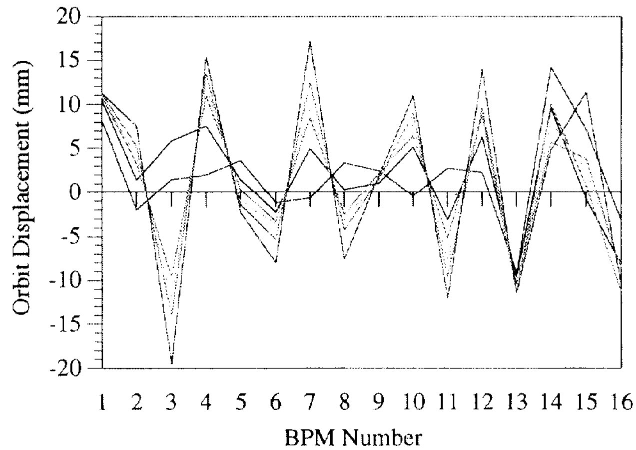

Fig 2. Orbit Drift from June 1993 to January 1994

Monitoring of storage ring elements has shown movements of quadrupole magnets during the energy ramp from 600 MeV to 2 GeV, and over the duration of a stored beam, related to thermal effects. Long term drifts in the orbit have been correlated to the continual cycling of these magnets [3]. Furthermore there is an amplificaiton factor associated with orbit errors due to quadrupole misalignment. In the case of the SRS, a single quadrupole error will be amplified by 8.46 in the orbit error.

Such deterioration of the orbit over a period of say 12 months leads to the situation where correction to a flat orbit becomes difficult due to excessive demand on corrector elements. Under these circumstances a correction of the orbit is carried out by re-alignment of a number of quadrupole magnets in order to reduce the bare orbit RMS deviation, and simultaneously the corrector strengths required for flat orbit.

5. PREDICTING OPTIMUM QUADRUPOLE MOVES

Prediction of the best magnet moves to correct the horizontal bare orbit is a multi-parameter optimisation which must strike a compromise between many things. The improvement to the orbit (usually quantified by the RMS) as a function of the number of magnets moved must be considered. A re-alignment of 2 or 3 magnets has been seen to give acceptable results. There is little to be gained over this by moving more magnets when the upheaval required is taken into account. A further important consideration is the corrector strengths which will subsequently be required to flatten the orbit once a re-alignment has taken place. Ideally corrector strengths will be low, and distributed evenly around the ring. A third consideration must be accessibility of magnets. While some quadrupoles are easy to access, making re-alignment relatively straightforward, others, particularly in the area of injection, are obscured by shielding and other equipment, and re-alignment of these is a complex and time consuming exercise.

Software is available in the form of an in-house code CORRECT, which employs the least squares method of orbit correction. CORRECT is used routinely on line to correct to flat orbit and predict single and combinations of most effective correctors. It can be used off-line to predict the best combination of a few correctors to reduce the orbit RMS. The magnetic lattice is configured such that horizontal steering magnets are adjacent to F-Quadrupoles, so a movement on a quadrupole can be simulated be applying current to a horizontal steer. A number of errors are apparent when performing such off-line predictions. The orbit used may differ slightly from the real orbit, however this has been seem to be a small effect. CORRECT assumes perfectly symmetric betas around the ring, and in reality this is not the case [4]. Tune differences may creep in, though with care this can be avoided.

6. ORBIT CORRECTION, JANUARY 1994

As shown in figure 2 the horizontal bare orbit of January 1994 had deteriorated significantly. Correction to flat orbit was difficult without saturating horizontal steering magnets (HSTR), which have an upper limit of 4A per winding. The steering requirements are shown in figure 3.

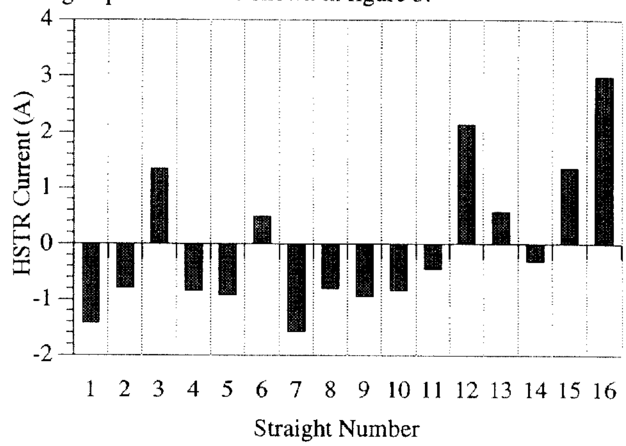

Fig 3. Steering requirements for flat orbit Jan. 1994.

Predictions for best single, two and three correctors were made using orbit data from 25% measured bare orbit, to eliminate BPM non-linearity errors. Best correctors are listed in the table below. The appearance of 16 and 3 are as would be expected from the flat orbit requirements. In a three corrector prediction, HSTR 11 was also of importance. Given the low demand on this corrector in the flat orbit, a further assessment was made with the inclusion of HSTR 12. Clearly the greatest part of the improvement occurs with two corrector magnets.

Magnet Currents Predicted (A)				Predicted
HSTR 16	HSTR 03	HSTR 11	HSTR 12	RMS (mm)
3.08	-	-	-	5.51
1.96	1.87	-	-	3.31
2.12	2.38	-0.73	-	3.10
1.90	-1.94	-	0.76	3.12

Table 1 Predictions for Orbit Correction

Predictions are tested using 2 GeV beam. While the 600 MeV orbit is different to that at 2 GeV, correction at the lower energy is always well within the capability of the steering magnets. Using a 2 GeV beam the prediction was tested by applying suitable currents to HSTR magnets, thereby simulating magnet moves. The 2 magnet prediction gave a good improvement to the RMS under test conditions. The corrector requirements for flat orbit following a correction as implied here were also assessed and seen to be well within the capability of the system.

7. MOVEMENT OF MAGNET UNITS

Quadrupole magnets are mounted on a stand as shown in Fig 4. Alignment in the vertical and transverse plane is carried out by means of adjustment bolts A and B respectively. Under normal running conditions these bolts are held in place with locking nuts so that no movement can take place. Both quadrupole and steering magnets are mounted on a common mechanism.

During re-alignment depth gauges are placed in proximity to the magnet at either end of the mounting plate to avoid any rotational movement. Once the locking nuts are loosened the magnet can be moved the small distance required by turning the adjuster bolts B, and monitoring the change on the depth gauges. Locking nuts are secured at the end of the exercise.

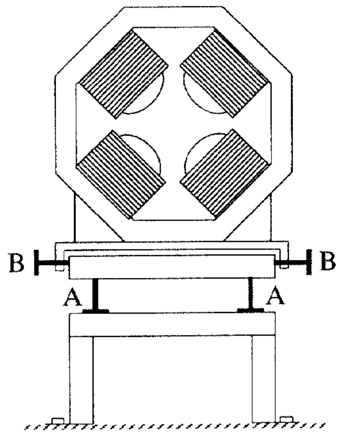

Fig.4 Schematic diagram of quadrupole mounting

Following the predictions detailed earlier, movement of the F Quadrupoles in straights 3 and 16 was carried out. A correlation of +3A HSTR current = 2mm movement radially outward is used to calculate the amount of realignment required. Both magnets were moved outward by 1.3mm.

8. RESULTS OF MAGNET MOVE

Injection is generally achieved easily following a magnet move, by using standard files and applying steering to nullify the effect of the move. Once beam is established, new steering and injection parameters can be optimised. An assessment of the new bare orbit was then carried out at 2 GeV and the flat orbit correctors assessed. The results compared favourably with the predictions. Figure 5 shows the predicted and achieved bare orbit.

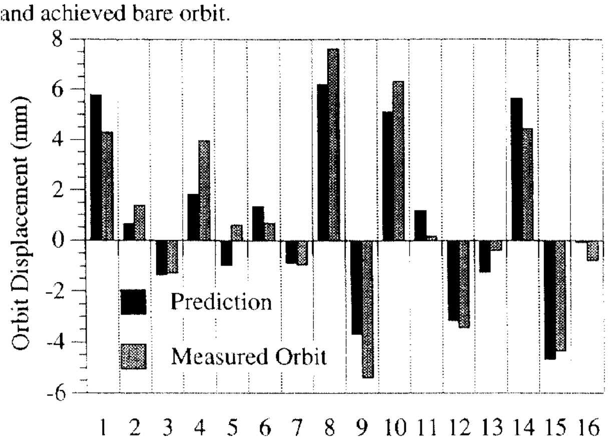

Fig. 5 Predicted and Actual Bare Orbits following Magnet Re-Alignment

The RMS orbit displacement is improved from 11.4 to 3.59mm. HSTR correctors required for flat orbit correction following the magnet move were significantly improved, and flat orbit could be achieved easily without approaching the saturation limit of any of the steering magnets.

9. PREVIOUS MAGNET MOVES

A number of similar re-alignment exercises have taken place in the past, in general with successful results. In recent magnet moves a more thorough assessment of the expected results has been carried out prior to beam time, and this has been found to be a valuable time saver, though the results cannot be relied upon to give first time accuracy. Table 1 summarises some previous exercises, and compares predicted with actual results.

Date	RMS (mm)	Move Magnet	Dist.	Predicted RMS (mm)	Measured RMS(mm)
15/7/88	10.18	FQ09 FQ07 FQ11	2mm 1.18mm 1.35mm	2.49	2.56
20/6/89	9.72	FQ09 FQ06	2mm 1.3mm	1.51	2.78
7/2/91	10.92	FQ09 FQ02 FQ09	2mm -1.7mm -0.9mm	2.64	2.86
9/9/91	13.84	FQ03 FQ07	2mm -1.1mm	3.2	3.69
8 magnets realigned following wiggler installation					
15/12/93	6.78	FQ10 FQ05 FQ15	-1.33mm 1.26mm -0.59mm	2.94	3.22

Table 1. Previous Magnet Moves to Correct Horizontal Orbit

10. CONCLUSIONS

During extended periods of operation the SRS electron beam orbit is seen to deteriorate to the point where steering becomes difficult. A method of correcting the orbit by realignment of F-Quadrupole magnets has been developed, which is shown to have largely successful results. Good comparison can be drawn between predicted and achieved results. Magnet moves are required at approximately yearly intervals. This method of orbit correction is of course a remedy rather than a cure for orbit drifts, and further work is ongoing to investigate the nature of movements of quadrupole magnets during operation of the SRS [3].

11. REFERENCES

1. T Ring and R J Smith, Orbit Measurement Techniques at Daresbury, Proc ABI Conf., Tsukuba, Japan, April 1991
2. S L Smith and L A Welbourne, Bump Compensation and System Error Detection Using an Excel Spreadsheet, These Proceedings.
3. J A Balmer, L A Welbourne, A Study of Thermally Induced Movement in SRS Storage Ring Quadrupole Magnet, These Proceedings.
4. M W Poole et al. Wiggler Tune Shift Compensation in the Daresbury SRS, Proc. IEEE Particle Accelerator Conference, Chicago 1989 p 208 - 210.