RECENT IMPROVEMENTS IN VERTICAL ORBIT FEEDBACK AT THE DARESBURY SRS

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Abstract

A vertical orbit feedback system has been in routine operation at Daresbury since 1994 and plays an important role in providing stable beams for users. This system was based, until recently, on a local feedback scheme, which stabilised the vertical orbit at each line using a single photon monitor and a closed three magnet bump. This paper reports the improvements in stability achieved with a new global vertical feedback scheme, which uses the same magnets and monitors but is based on an SVD correction algorithm. The simulation and initial commissioning of the scheme was carried out using an EXCEL based program. This provided a flexible and fast development environment and allowed the speedy implementation of the new scheme for routine operations.

1 INTRODUCTION

Orbit control has been employed at Daresbury to stabilise the photon beam position routinely since 1994. The global horizontal feedback system [1] currently used routinely, reads the horizontal electron orbit at 16 electron beam position monitors (BPMs) and applies a global correction at the 16 steering magnets (HSTRs), the strength of the correction is determined by a simple inversion of the steering magnet response matrix. The orbit is read and a correction is applied every 30 sec. Until recently vertical orbit feedback was operated locally at many of the beamlines [2]. Tungsten vane monitors (TVMs) on the beamlines provide a position signal and local three magnet bumps were used to correct this every 30 sec.

With the introduction of new beamlines in the SRS a three magnet bump was no longer sufficient to independently correct the position at each monitor and this necessitated a re-think of the philosophy for vertical orbit control. When local vertical feedback was first commissioned, with very few of the 11 beam ports on the SRS having beamlines with a reliable vertical monitor, a single monitor feedback system was the practical way forward. However now that every port has at least one beamline with a TVM monitor, the sampling of the orbit is good enough to consider a global vertical scheme based on these photon monitors.

2 CORRECTION USING SVD

The SRS has is a 16 cell FODO lattice with one vertical electron beam position monitor VBPM and two vertical correctors per cell. The layout is shown in figure 1. 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.

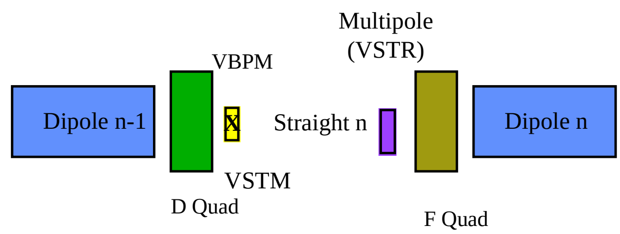

Figure 1: Schematic showing position of vertical correctors and monitors in an SRS lattice cell.

Currently there are eight fully commissioned dipole ports on dipoles 1,2,3,4,6,7,8 and 13, two super-conducting wiggler ports in straights 9 and 16 and an undulator port in straight 5. The distribution is shown in figure 2.

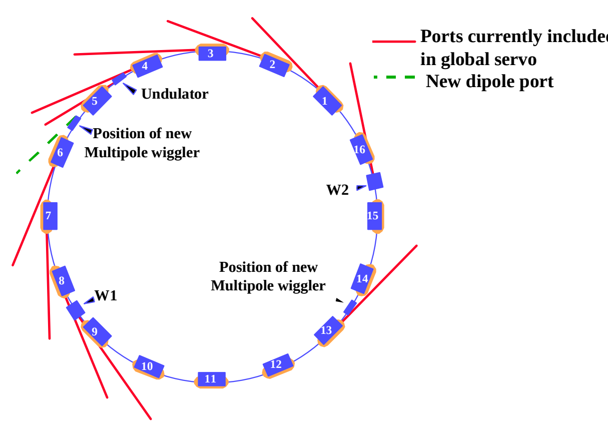

Figure 2: Distribution of TVMs around the ring

Each port has one TVM except super-conducting wiggler, W2, 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. To summarise, this gives a total of 11 possible TVMs, 16 VBPMs and 2 x 16 vertical correctors for inclusion in any global correction scheme..

An EXCEL program [3] 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. This was very simple to implement as the program made use of the already written accelerator physics module (APM) [3] which is an EXCEL module written to provide a user friendly interface to the PC based control system. and the accelerator physics simulator (APS), a replacement module, which provides a machine simulator for use off-line. As this program was to be used as a testing and commissioning aid it was designed to allow the choice of any combination of correctors and monitors in the vertical plane.

The programming was done using Visual Basic for Applications with the input and output via EXCEL spreadsheets. 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 following list summarises the main features and the options available in the program.

1. Choice of any combination of correctors and monitors in the vertical plane.
2. Correction only when minimum RMS orbit is exceeded.
3. Correction of “easiest” portion of the orbit to a minimum RMS by using the most effective corrector sets.
4. Application of correctors in steps.
5. Averaging of monitor readings
6. Debug option with output of all matrices.
7. Full logging of data.

In addition, the program run in simulation mode has the following options.

1. Random monitor and corrector errors.
2. Rounding to least significant bit on correctors.
3. Response matrix errors.

3 GLOBAL FEEDBACK

The photon monitors were used for feedback because of problems with the position stability of the vertical electron beam monitors 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 operational ports. In fact the simulations showed that when correcting very small residual orbits, this reduced number of correctors improves the correction because of the reduction in the number of corrector setting errors caused by the bit resolution of the DACs. It practice a reduction in the residual noise on the TVMs was found when the bit setting errors on the VSTM magnets was reduced by a factor of 4.

A simplified version of the correction program has been used for operations. This EXCEL program is automatically configured to use the 16 VSTM magnets and any combination of the 11 TVMs. The system has been designed to deal with the slow drift in orbit due to thermal effects in the machine which can be several 100 microns over a stored beam of up to 22 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 3 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 4 shows a prediction of the drifts which would have occurred during the same period without the feedback on.

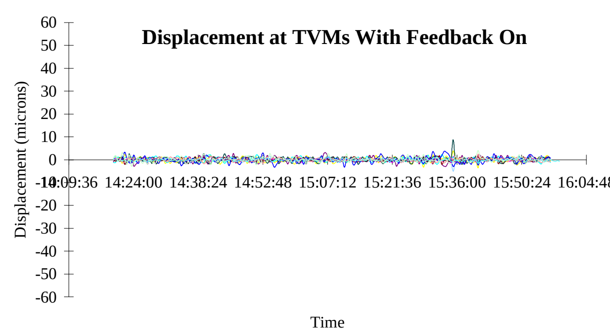

Figure 3: Operation of global vertical feedback on the photon beam monitors during a user beam.

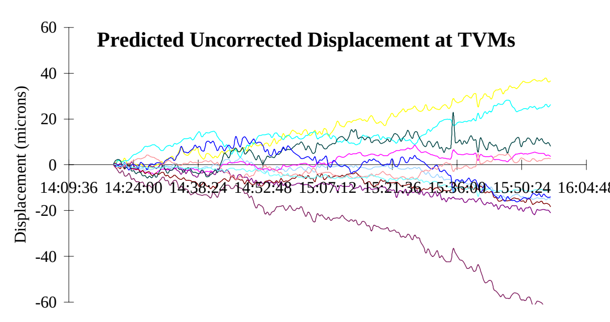

Figure 4: Predicted drift at TVMs without feedback

To operate with a user beam, 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 system rapidly detects a port closing by monitoring the individual vane currents on the TVMs. A limit on the maximum monitor error and integrated monitor error ensures that a monitor failure is detected before any harm is done. A considerable benefit of the global feedback over the local feedback system is the ability to reduce the drift at a port even when a TVM is removed from the correction scheme. This has been observed during tests where a monitor was deliberately removed from the feedback system and monitored.

4 DEVELOPMENTS

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, predicting 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 were recorded with and without correction at the new TVM. The results are shown in figure 5. These show clearly that the 16 magnet solution would require the use of relatively very strong correctors. This would be impractical, as the increased sensitivity to realistic errors in response would produce unacceptable errors.

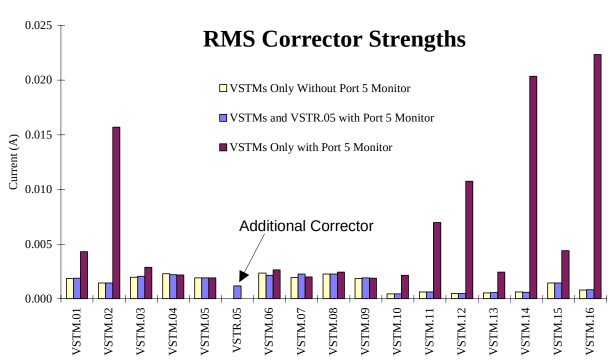

Figure 5: RMS corrector strengths required to correct the orbit at the TVMs with and without dipole 5 TVM.

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 in 1999 with the addition of two new multipole wigglers in straights 6 and 14.

Originally it was planned to implement the SVD global vertical correction on the front end computer running VME. This would be essential if the system was to be run at the maximum possible update rate. However while the requirement is only to correct the slow orbit drift, a program running at the higher level on the PC system offers the greatest flexibility. A new combined global correction and port monitoring program has recently been implemented in Visual Basic. This uses basically the same correction code but has a completely dedicated interface which runs without the overhead and constraints of EXCEL. It is envisaged that this program will be extended to encompass the horizontal feedback system, replacing the current simple matrix inversion with SVD. This will then allow horizontal feedback to continue operating even in the event of a position monitor failing.

Trials are planned to assess the practicality of correcting both position and angle at one or two ports, either using two photon monitors at different distances from the source point or by including data from the electron monitors in the straight sections.

SUMMARY

To meet the demands of an increased number of beamlines in the SRS a new global vertical orbit feedback system has been developed which has already been demonstrated to be highly effective at providing stable photon beam. This system provides beam, stable to the micron level at a single monitor in a beamline on each port in the SRS. The foundation of the system is an EXCEL program with can be run on-line or off-line in a simulation mode This has been extremely useful as a development tool and has provided the basis for evolution to a multipurpose Visual Basic program for use in operations. The feedback system will be extended to cope with the new beamlines and the simulation program has already proved helpful in predicting how this can best be achieved. Other developments such as the simultaneous correction of position and angle may be investigated in the future.

REFERENCES

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