A Digital Feedback System for Orbit Stabilization*

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Abstract

We are reporting on the design and preliminary results of a prototype digital feedback system for the storage rings at the NSLS. The system will use a nonlinear eigenvector decomposition algorithm. It will have a wide dynamic range and will be able to correct noise in the orbit over a bandwidth in excess of 60 Hz. A Motorola-167 CPU board is used to sample the PUE's at a minimum rate of 200 Hz and an HP-742rt board is used to read the sampled signals and to generate a correction signal for the orbit correctors.

1 Introduction

In synchrotron radiation facilities the stability of the orbit (*i.e.* the time dependent changes in the orbit) is extremely important. An unstable orbit reduces the effective brightness of the photon source and increases the dynamic aperture of the beam thus reducing lifetime. Usually, the orbit can be stabilized with a feedback system. At present there are two feedback systems operating at the light source. A global feedback [1], using an harmonic correction algorithm, and a local feedback [2] that achieves higher beam stability at the insertion devices. The feedback systems are very successful at reducing beam noise at frequencies of up to 50 Hz. However, above 30 Hz there is a significant reduction of gain in the system.

After the present feedback systems were implemented, significant noise was observed at frequencies above 50 Hz. Thus, there is a need for a higher bandwidth of the feedback system. In addition, the present systems are based on analog hardware. Hence, they are not flexible to changes in the algorithm. It is therefore beneficial to develop a digital feedback system that will satisfy the present needs and will be flexible enough for future improvements.

2 Algorithm used

In implementing the digital feedback system, we are using the eigenvector decomposition based orbit correction method described in Refs. [3, 4]. This method will yield the 'minimum' kick vector required for a desired accuracy of orbit correction.

For any given circular machine, the response matrix A 'translates' between a $\vec{\Theta}$ kick vector and the resulting $\vec{X}$ orbit change:

$$\vec{X} = A\vec{\Theta} \tag{1}$$

In general, the number of correctors and monitors are different, consequently the response matrix A is rectangular. Let λ_j be the eigenvalues and $\hat{\theta}_j$ the corresponding eigenvectors of the $A^T A$ matrix. The orbit change corresponding to the j-th eigenvector is:

$$\vec{x}_j = A\hat{\theta}_j \quad . \tag{2}$$

The $\vec{X}_o$ orbit to be corrected is essentially decomposed in terms of these $\vec{x}_j$ 'eigen' orbits:

$$\vec{X}_o = \sum_{j=1}^{N_c} c_j \cdot \vec{x}_j \quad , \tag{3}$$

where

$$c_j = \vec{X}_o \cdot \vec{x}_j \quad . \tag{4}$$

Substituting Eq. (2) into Eq. (3) we obtain

$$\vec{X}_o = A \sum_{j=1}^{N_c} c_j \hat{\theta}_j \quad , \tag{5}$$

that is, the kick vector which corrects the $\vec{X}_o$ orbit, can be obtained from the eigenvector decomposition of this orbit as:

$$\vec{\Theta} = \sum_{j=1}^{N_c} c_j \hat{\theta}_j / \sqrt{\lambda_j} \quad . \tag{6}$$

3 Architecture

3.1 Hardware

The system will rely, mostly, on existing hardware with several modifications. The basic layout is depicted in Fig. 1. There are four micros involved. The PUE micro will sample the PUE data at 200 Hz rate (but with sampling time of 2 msec). The data is then transfered to the feedback micro which calculates the orbit correction and optimizes it. The kick values are then transfered into the trim micro which, in its turn, sets the new values to the trims power supplies. The communication between the micros is done directly on the VME bus through shared memory. The most computational intensive task is that of the feedback micro. Hence, we chose an HP 742rt, which we estimate to run six times faster than a Motorola 167/162 for that kind of application. We have added a fourth micro (control micro) to the design in order to isolate the PUE and feedback micros from the general control

*Work performed under the auspices of the U.S. Dept. of Energy under contract no. DE-AC02-76CH00016.

network. These micros are expected to operated at close to full load. Thus, any requests addressed to them on the network may slow them down, reducing the feedback rate. The control micro will sample the PUE micro at 20 Hz and will make this data available to workstations for existing control programs [5] such as Real Time Orbit, Fast Orbit History, *etc.* This micro will also send commands to the feedback micro and display data on its status. If the need arises, it is possible that either the PUE micro or the feedback micro will write 200 Hz orbit history to a DAT tape.

In order to prevent aliasing problem the PUEs will be set up with an analog low pass filter of a 100 Hz.

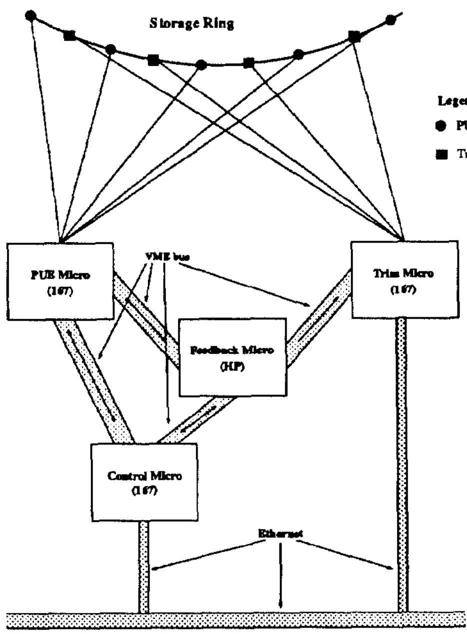

Figure 1
Layout of the feedback system.

3.2 Software

The PUE, trim and control micros will use the existing monitor [6]. Their programming will be modified to place the read points and set point into shared memory, and to synchronize data collection with the feedback micro. The device read points for the PUEs will be read through the control micro, and will be updated at a frequency of 20 Hz, which is the present PUE sampling frequency. A new monitor will be written for the feedback micro, based on the HP-RT operating system. The orbit correction code is a modification of the code that was used for orbit correction in Refs. [3, 4]. This is an object oriented code written in C++.

4 Preliminary studies

4.1 Algorithm

A preliminary study was performed on the NSLS VUV ring, using the existing global feedback system. The eigen-orbits and eigen-kicks [3, 4] were fed to the feedback system instead of the harmonic data. The result was a reduction of 17 db in the noise up to 20 Hz. It is expected that the future system will perform much better since it include more trims and PUEs and it optimizes the kick values.

4.2 Timing

From preliminary study, we estimate the computation time in the feedback micro to be 1.5 msec/cycle. The sampling time of the PUEs is 2 msec and the writing time of the trims is 1 msec. It is, thus, possible to complete a cycle in 5 msec, which is the maximum time allowed in order to achieve 200 Hz rate. However, it is necessary to synchronize the operation of the three micros.

I. References

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