Automatic Local Beam Steering Systems for NSLS X-Ray Storage Ring - Design and Implementation*

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Abstract

Recently, two local automatic steering systems, controlled by microprocessors, have been installed and commissioned in the NSLS X-Ray storage ring. In each system, the position of the electron beam is stabilized at two locations by four independent servo systems. This paper describes three aspects of the local feedback program: 1) design, 2) commissioning and 3) limitation. The system design is explained by identifying major elements such as beam position detectors, signal processors, compensation amplifiers, ratio amplifiers, trim equalizers and microprocessor feedback controllers. System commissioning involves steps such as matching trim compensation, determination of local orbit bumps, measurement of open loop responses and design of servo circuits. Several limitations of performance are also discussed.

I. INTRODUCTION

During the year 1990, two local feedback systems were commissioned and are now fully operational: one for hybrid wiggler (HBW) at X25 beamline and the other for LEGS experiment at X5 beamline. These systems employ 4 trim magnet bumps for beam deflection and two beam position monitor detectors, which are all placed in the straight section. Previous work on stabilization of photon beams in a storage accelerator is described in [1] - [3] and a general introduction to all NSLS local feedback systems is presented in [4].

II. DESIGN

The block diagram of NSLS beam steering system is shown in Fig. 1. This beam steering system can be subdivided into three sections: 1. Beam position monitoring (PUE and RF detectors) 2. Beam actuators (Power supplies and Trim magnets) 3. Local feedback electronics. Sections 1 and 2 are discussed in details in [5] and [6] respectively. The last section, local feedback electronics, is discussed in this paper.

The local feedback electronics consist of the following modules: CPU/Communication, signal processors, ramping (on/off), compensation amplifiers, ratio amplifiers, summing and equalization amplifiers. All of these modules are housed in a VME crate which is linked to the host computer using CPU/Communication module. The signal processor module consists of differential receiver circuits to receive signals from the beam position RF detectors (located near the beam pipe) and the reference or target signal which is provided by the computer using a digital to analog converter. This reference signal is subtracted from the beam position signal to provide the error signal which then is used to drive compensation amplifier (servo) loops. It is desirable that the value of this reference signal be as close as possible to the value of beam position signal before closing the loop, so as to minimize the amount of initial trim correction generated by the system.

The ramping module consists of four multiplying digital to analog converters, one for each loop. There are two basic functions for this module; one is to provide a "soft" turn on/off function and other is to provide some dc gain control from the computer, if required. The "soft" turn on/off is achieved by sending digital set points to MDAC in small increments, so it creates a ramping effect. This feature is highly desirable because it minimizes the transients into the beam which can be introduced by turning loops on and off. The computer controlled dc gain provides a way to fine tune the loop gain without redesigning the servo circuits. Each compensation amplifier module consists of cascaded three stage amplifiers with each stage providing circuits to incorporate 2 poles and 2 zeros. This amplifier at X 25 beamline has 5 poles at 1.5 hz, 4 hz, 200 hz, 400 hz (2) and two zeros at 15 hz and 40 hz and a dc gain of 100 (40 db). This combination provides system bandwidth of 50 - 60 hz with a gain and phase margin of about 15 db and 45 degrees respectively.

The ratio amplifier module consists of four multiplying digital to analog converters for each loop. The output values of these converters are controlled by computer set points K_{1j} and K_{2j} for the two loops ($j = 1$ to 4) which then provides the proportional signals to the corresponding trims. The ratio values are critical to the performance of feedback system and are based on two conditions; the four magnet bump should be local and this bump should provide an angle bump such that while this bump moves the beam at one PUE location, it has

*This work was performed under the auspices of the U.S. Department of Energy.

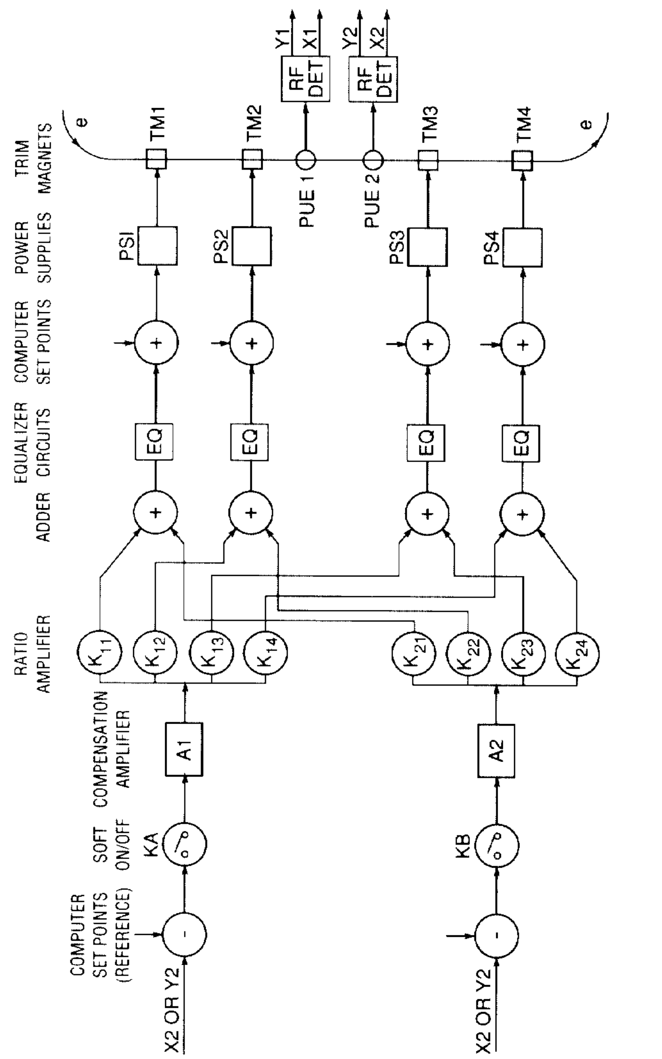

Fig. 1. Block Diagram of NSLS Beam Steering System

no significant effect on the second PUE location. In other words, the angle bump crosses at zero point at the second PUE. The output of four ratio amplifier signals from each detector is added correspondingly into the adder circuits. The equalizer amplifier circuits consist of cascaded two stage amplifiers with provisions of up to four poles and four zeros. The equalizer amplifiers are used to match the beam phase response of four trim magnets. This is necessary so that there is no phase distortion at higher frequencies, which could lead to an unstable feedback system. This module also provides high current drivers which drive these signals to power supply locations.

Since at NSLS storage ring, all the trim power supplies are used to set proper beam orbit by sending set points by the computer (see Fig.1), the feedback trim power supplies have summing junction to accept second input from the feedback electronics. However, computer set points for feedback trims should be kept as small as possible so as to allow large strengths to be utilized for automatic feedback correction system. This, however, is not always possible.

III. COMMISSIONING

The matching of beam phase responses for all trims can be quite important and sometimes difficult. Once all of the four phase responses are measured, the one which rolls off the fastest is used as a reference, while others are matched to this reference response utilizing the equalizer amplifiers.

As stated earlier, there are two independent loops for each plane, one designated for each detector. Each loop is to provide a stable beam at its detector. For these two loops to be decoupled, it is necessary to develop two sets of four magnet bumps such that while each loop moves the beam at its own detector it causes little or no disturbance at the other one. To achieve this, the first three magnet local bumps are determined by special programs [7]. Using this program, two sets of local bumps are determined, first by using trims 1,2,3 and then by using trims 2,3,4. From these two sets of three magnet bumps, two sets of four magnet bumps are developed as follows:

Say, K_{1j} and K_{2j} represent the bump coefficients for above mentioned two sets of three magnet bumps, where j = 1 to 4 (note $K_{14} = K_{21} = 0$). Using these bump coefficients in the ratio amplifier, the beam motion at detectors 1 and 2 are determined when a signal is injected at the input of ratio amplifier (say these are D_{11} and D_{12} due to 1st bump and D_{21} and D_{22} due to second bump). The two decoupled four magnet bumps (K_{1j}' & K_{2j}') can be written as

$$K_{1j}' = K_{1j} - (K_{2j} \cdot D_{12}/D_{22})$$

$$K_{2j}' = K_{2j} - (K_{1j} \cdot D_{21}/D_{11})$$

These calculated bump coefficients are inserted into the ratio amplifiers and the open loop system responses are measured. For X25 beamline, the dc response is about 0 db for vertical plane and about -8.5 db for horizontal plane while the phase response crosses 180° between 400 to 600 hz for horizontal and vertical planes.

IV. RESULTS

Two local feedback systems have been employed successfully and are fully operational on the NSLS X-ray ring beam lines X5 and X25. The results from X25 beam line are shown in Fig.2. Two RF detectors are connected to PUE 30 and PUE 31 and are used for this local feedback. The top trace in Fig 2 shows the chart recorder data of the vertical beam motion in time domain with vertical feedback on and off. From this trace, we see that the beam motion induced by the NSLS Booster (at approximately 0.66 Hz) is clearly reduced, when loops are turned on. The bottom trace is the frequency spectrum of the vertical beam motion at PUE 31 with the loop on and off. The improvement at the second

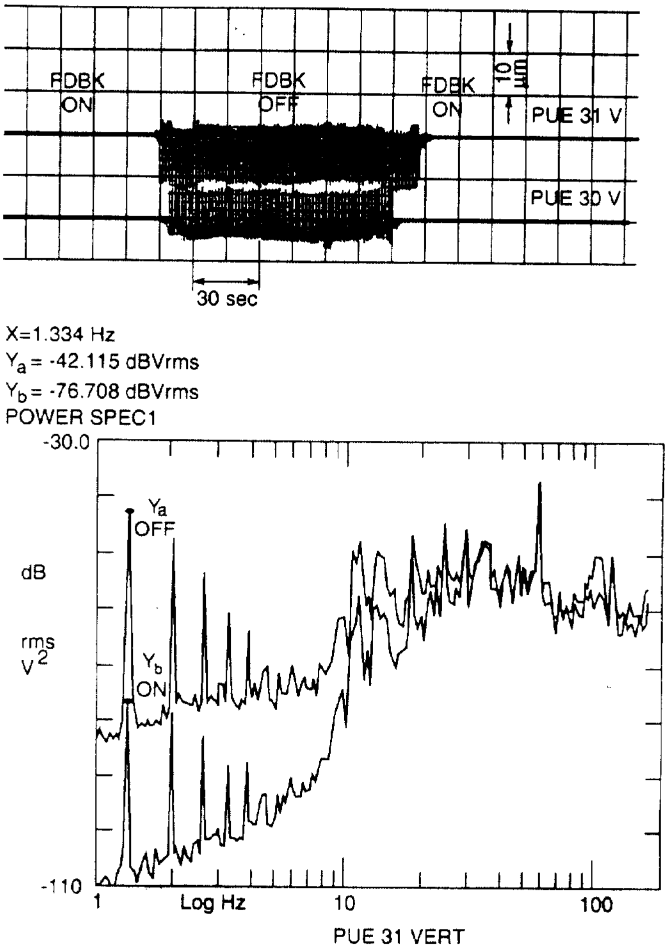

Fig. 2. Beam Motion Reduction with Feedback On.

harmonic of the NSLS Booster is better than 33 db as shown by peaks Ya and Yb which translates to an improvement from 4.4 μm (p-p) to 0.08 μm (p-p). (20 db = 5.6 m p-p).

V. LIMITATIONS

Since the feedback trim power supplies also are used for orbit correction, the full trim strength may not be available for the correction system. Thus this reduces the feedback correction range. Further, if the initial setting of a trim is too high, and a large amount of correction is required, it is possible that that trim will saturate while other three trims are still in the active range. This can result into a non local bump and thus cause undesirable global beam motion. This condition of high initial setting does occur for one trim in NSLS ring and this problem has been recently solved by providing two seperate power supplies for this trim, thus increasing its strength.

In the horizontal plane, the beam motion range for a given fill (200-500 μm) is far greater than the range of the feedback system (100 μm). At present time, several global orbit corrections are made during each fill so that the feedback correction demand is reduced.

V. ACKNOWLEDGEMENTS

G. Frisbie was involved in the development and construction of all the feedback circuit boards and in the assembly, testing and commissioning of the overall system.

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