Real Time Global Orbit Feedback System for NSLS X-Ray Ring*

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Abstract

We report on the design and commissioning of a real time harmonic global orbit feedback system for the NSLS X-ray ring. This system uses 8 pick-up electrode position monitors and 16 trim dipole magnets to eliminate 3 harmonic components of the orbit fluctuations. Because of the larger number of position monitors and trim magnets, the X-ray ring feedback system differs from the previously reported VUV ring system in that the Fourier analysis and harmonic generation networks are comprised of MDAC boards controlled by computer. The implementation of the global feedback system has resulted in a dramatic improvement of orbit stability, by more than a factor of five everywhere. Simultaneous operation of the global and several local bump feedback systems has been achieved.

I. INTRODUCTION

Stability of the electron orbit is critical for the utilization of a low emittance storage ring as a high brightness radiation source. We have previously reported [1,2] on the development of a global real time closed orbit feedback system on the VUV ring of the NSLS at BNL which significantly improved the orbit stability. Recently, based on the experience with the VUV ring global orbit feedback system, we developed a vertical global orbit feedback system for the X-ray ring. Compared to the VUV ring feedback system, the new X-ray ring system eliminates 3 harmonic components of the orbit distortion, instead of only one. In the low frequency circuits of the new system, we used MDAC (Multiplying Digital to Analog Convertor) to replace the potentiometers in the Fourier analysis networks. This makes the new system more accurate and easier to install than the VUV ring system. Since February 1991, the X-ray ring system has been in routine operation and has provided an even more pronounced improvement of the orbit stability than the VUV ring system. During installation we also developed a method to decouple several local feedback systems and operate them simultaneously with the global system. The global system not only greatly reduces the orbit movement, but it significantly reduces the required feedback correction strengths of the local feedback systems.

Harmonic global orbit correction uses the fact that the orbit distortion is dominated by its harmonic components nearest to the tune. To carry out a real time harmonic orbit correction, we first measure the orbit, then Fourier analyze its displacements. The Fourier analysis is done by a simple linear analog network F. The input voltages are proportional to the orbit displacements at the detectors, and in real time the output voltages are proportional to the desired Fourier harmonic coefficients. Another linear analog network T is used to generate the desired orbit displacement with required Fourier coefficients. The input voltages are proportional to the desired Fourier coefficients, and the output voltages are proportional to the trim currents required to generate the desired orbit correction. When these two networks are connected by servo circuits, the Fourier components in the orbit distortion are forced to vanish.

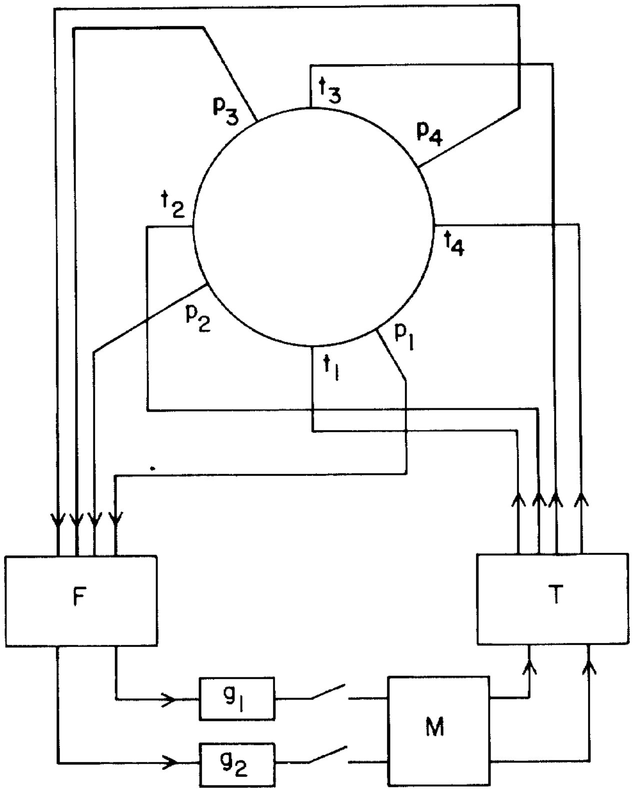

Fig. 1

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Based upon these two networks, the feedback system is illustrated in Fig. 1. For simplicity, we show the VUV ring feedback system, which has 4 position detectors, 4 correctors, and corrects the sine and cosine components of the first harmonic of the orbit distortion. The output of the PUE's are the four inputs to the Fourier analysis matrix network F. The output of F are the voltages corresponding to the two Fourier coefficients. Thus the F matrix is a 2 by 4 matrix. The linear network 4 by 2 matrix T is used to generate different trim current combinations, corresponding to different harmonic components of the orbit correction.

II. THE X-RAY RING GLOBAL FEEDBACK SYSTEM

Now let us turn to the X-ray ring global feedback system. The X-ray ring has 8 superperiods, with a vertical betatron tune 6.2. We select 8 PUE's and 16 trims, symmetrically distributed around the ring, with one PUE and 2 trims per superperiod. We eliminate 3 harmonic components of the orbit distortion with 6 channels, corresponding to $\cos 5\phi$, $\cos 6\phi$, $\cos 7\phi$, $\sin 5\phi$, $\sin 6\phi$, $\sin 7\phi$. Thus we generalize the matrix F to a 6 by 8 matrix, and the matrix T to a 16 by 6 matrix. Simulation shows that the system should reduce the maximum displacements by a factor 5, and the rms displacements by a factor 6, for the worst noise source location.

The F matrix circuit for the VUV ring feedback system consists of many potentiometers, each corresponding to one matrix element. Since the X-ray ring system has much larger F and T matrices, we decided to use MDAC (multiplying digital to analog converter) instead of the potentiometers. The output signal of an MDAC is equal to the input multiplied by a ratio determined by a digital input from a computer. Hence we can think of an MDAC as a digitally controlled potentiometer. Both the F and T matrices are made of a number of MDAC boards, each of which has 16 MDAC's. The MDAC boards are designed to be modular, so that they can be assembled in many different ways to form either F or T matrices with different numbers of input and output channels. For example, the F matrix circuit is a crate, which consists of 6 MDAC boards. The 8 PUE receiver output signals are wired to all of the 6 boards, providing the 8 inputs for each board. Each board corresponds to one of the 6 Fourier coefficient channels. Thus, the MDAC boards can be mass produced, and used for not only the X-ray ring vertical orbit feedback system, but also the X-ray ring horizontal orbit feedback system and future upgraded VUV ring systems.

Initially, the F and T matrices are calculated by theory, and loaded into the F and T crates. Then the 6 by 6 response matrix R, from the input of the T matrix to the output of the F matrix is measured experimentally. Next, the inverse matrix of R is multiplied to the T matrix to generate a new T matrix, and loaded into the T crate again. Then the process is iterated. It is easy to realize that the new response matrix, measured after the new T matrix is loaded, is ideally a unit matrix. Actually, we found that after only one iteration, the off-diagonal elements of the R matrix had become 40dB smaller than the diagonal elements, providing 6 independent channels, each controlling one Fourier coefficient of the orbit distortion.

When we closed the servo feedback loops of all the 6 channels, we obtained the predicted improvement of the orbit stability. Fig. 2 shows both the long term and short term beam position movement at PUE31 when we turned on and off the global feedback loops every 30 minutes within an 8 hour machine study period. We took 16 different measurements such as the one shown in Fig. 2, measured the maximum excursions (peak to peak) for both open and closed loops, and the results are plotted in Fig. 3 as the maximum excursion vs. the PUE number, providing a clear picture of the global improvement.

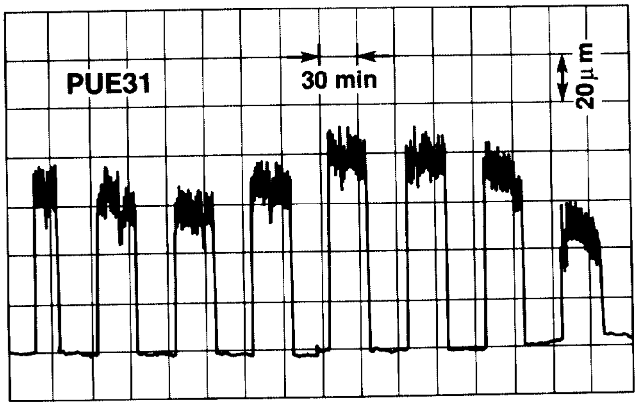

Fig. 2

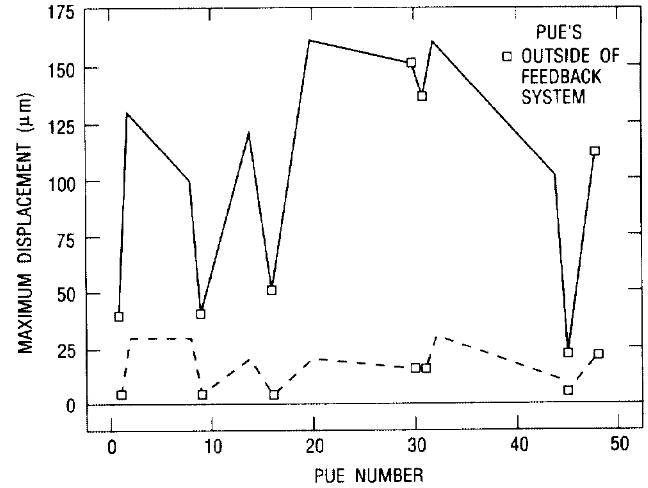

Fig. 3

III. DECOUPLING THE GLOBAL AND THE LOCAL FEEDBACK SYSTEMS

On the X-ray ring there are local bump feedback systems [3,4] for insertion devices. It happens that inside the local bumps there are PUE's used in the global feedback system. Because the global system responds to the driving signal in the local feedback loop through the signal from these PUE's, there is a coupling between the local and global systems. We have developed a procedure to obtain stable simultaneous operation of the local and global systems, by measuring the open loop response of the local systems with the global feedback loops closed.

In Fig. 4, we show the results of this global-local combination system. The top part of the diagram is the signal from one of the PUE RF receivers in a local feedback loop. The lower part is the correction signal in one of the local feedback loops. When both global and local loops are open, the correction signal is zero, and the beam movement amplitude is about 10 μm. When only the local feedback loop is closed, the beam motion is reduced to 2 μm, but the correction signal is large. However, when both the global and the local feedback systems are closed, the beam motion is further reduced to about 1 μm, and the local correction signal reduces by a factor of 5.

This result shows that the global feedback system can greatly reduce the field strengths of the local feedback systems. This will be particularly useful when the orbit excursion is very large and pushes the local feedback system near saturation, as happens sometimes for the horizontal orbit local feedback systems in the X-ray ring.

The new X-ray ring vertical global feedback system has been in operation since the beginning of February 1991. It dramatically improves the orbit stability. One example is shown in Fig. 5, where the X-ray intensity fluctuation from a sample in the AT&T beam line X16A, measured during three different periods (Nov. '90, Jan. '91, and Feb. '91) are plotted, showing a very large reduction of the fluctuation at the experiment after the global system went into operation.

IV. REFERENCES

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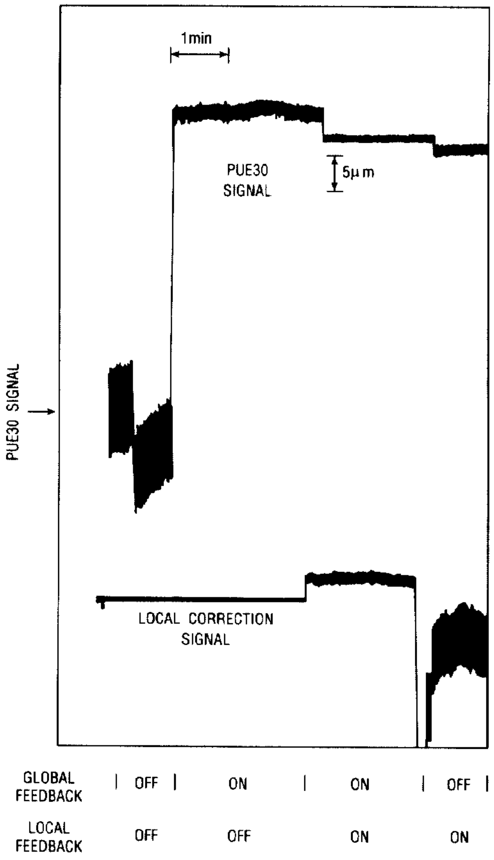

Fig. 4

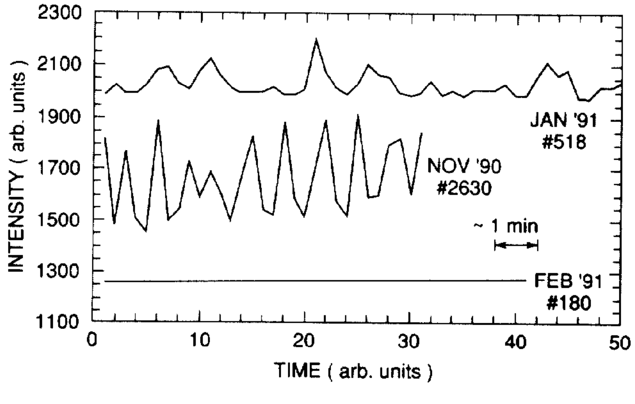

Fig. 5