

DEVELOPMENT OF A BPM LOCK-IN DIAGNOSTIC SYSTEM*

R Dickson, Jefferson Lab, Newport News, VA 23606, USA

Abstract

A system has been developed for the acquisition and analysis of high rate, time coherent BPM data across the Jefferson Lab's Continuous Electron Beam Accelerator Facility (CEBAF). This system will allow the acquisition of Beam Position Monitor (BPM) position and intensity information at a rate in excess 7 KHz for approximately 200 BPMs in a time synchronous manner. By inducing minute sinusoidal transverse beam motion in the CEBAF injector, with known phase relative to the synchronized BPM acquisition, it is possible to derive several types of useful information. Analysis of the BPM intensity data, which is proportional to beam current, by beating the signal with an in-phase sinusoidal representation of the transverse kick can localize beam scraping to a particular BPM. Similarly, real-time optics information may be deduced with an analysis of BPM position data. This paper will detail the frequency lock-in technique applied and present status.

INTRODUCTION

The CEBAF accelerator is a five pass CW recirculator, which can reach an energy of 6.067 GeV. It consists of a 67 MeV injector, two superconducting 600 MeV linacs, and 9 arcs of magnets which connect the linacs for beam recirculation. See figure 1.

The accelerator's BPM system includes more than 850 BPMs, controlled by two different types of electronics, distributed across a network of 30 Input Output Controllers (IOCs). Of interest in this discussion is one of the two types - the Switched Electrode Electronics (SEE) BPM [1] system, hereafter referred to simply as BPM.

In order to improve machine reproducibility and reduce beam tune time, a differential orbit '30 Hz' measurement system is used. This system makes it possible to track and correct machine optics by measuring the differential response generated by perturbations of the beam. By means of a small set of correctors, one can induce a beam perturbation at a frequency of 30 Hz. The effect of this perturbation is potentially apparent at any BPM point in the machine. The BPM system performs data acquisition at 60 Hz synchronized with the beam pulse. The choice of 30 Hz as the perturbation frequency enables synchronization of every other beam pulse to the positive or negative crest of the perturbation signal.

This system is limited to operation with 60 Hz pulsed beam due to the relatively large magnitude of kick applied, and is not used with continuous wave (CW) beam for machine protection reasons. Since the machine end-users are interested in delivery of continuous beam, this system is generally only used during machine set up or as

a diagnostic tool when problems arise. Obtaining a similar diagnostic tool that is usable during CW beam delivery is desirable. The development of such a tool is the focus of this paper.

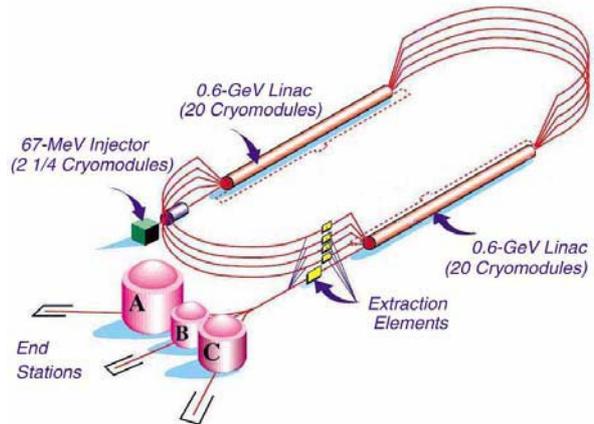


Figure 1 Machine Configuration

SYSTEM COMPONENTS

The ability to create a real-time, CW-beam, differential orbit diagnostic tool requires leveraging and integrating several existing lab diagnostic systems. These include the lab's Beam Scraping Monitor (BSM), 30 Hz Timing Synchronization System (TSS), and FastSee high speed BPM data acquisition system. Each of these systems are overviewed below.

The BSM system [2] applies a minute perturbation to the transverse beam orbit and detects resultant current fluctuations due to beam scraping. The kick is applied with air-core magnets in the machine's injector at four distinct frequencies. Two frequencies are applied to each of the horizontal and vertical axes. For each single axis, two kicks are spaced at roughly 90 degrees of relative betatron phase advance. The resultant differential orbit is of magnitude well below 100 microns. Four lock-in amplifiers are used to generate the perturbation signals and detect the beam current effect at the same frequency and phase using as input an attached beam current monitor (BCM) cavity.

The accelerator has its own 60 Hz AC line synchronized global timing reference called the Beam Sync. The BPM system uses this signal for data acquisition synchronization. The purpose of the TSS [3] is to allow the 60 Hz BPM system awareness of the polarity of the 30 Hz diagnostic's kick at each acquisition. The hardware-based TSS uses one master clock module and

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multiple slave clock modules. These 3U sized cards share the VME bus with the SEE BPM front end (IOCs). The communication flow, from master to slave boards, occurs over a single fiber optic line originating from the master. Each card has a fiber optic receiver and repeating transmitter. The last card in the chain is connected back to the master. This enables the master to perform a continuity test of the entire link. Like the beam synch, the frequency of the message passing is AC line synchronized 60 Hz. The message from the master to the slave timing modules contains status and global synchronization information. Since the sole usage of its fiber link is for this timing synchronization and there is only one source of messages, this system guarantees synchronization to a time approximately equal to the maximum round trip time for a message. Worst-case delay from received input to re-transmitted output per module is less than 1.5usec. In a complete implementation, with up to 100 IOCs participating, the total round trip time will be 150usec. This is far more accurate than needed to identify one 16.67 millisecond beam synch period from another.

The standard data acquisition mode of the BPM system digitizes position and beam current dependent intensity information at an effective rate of 60Hz. This data is further averaged to update operator displays at a 1 Hz rate. A high-speed mode exists to provide the display of position and intensity at the maximum rate possible for the BPM electronics in the form of time-domain X-Y plots and Fast Fourier Transforms (FFT). This mode is named the FastSee system. There are two flavors of SEE BPM electronics. One operates at a maximum data acquisition rate of 7.1 KHz and the other at 125 KHz. For simplicity of discussion, the 7.1 KHz version will be assumed in the following discussion.

INTERGRATING COMPONENTS TO THIS LOCK-IN SYSTEM

This lock-in system uses the differential orbit created by the BSM kick to provide a display indicative of the local relative phase advance. The four frequencies at which the BSM system modulates the transverse motion of the beam are 805.3, 867.7, 934.7, and 994.8 hertz. These frequencies were somewhat arbitrarily selected, but are spots of relatively low background noise for the machine.

In order to detect this motion, the FastSee mode of BPM data acquisition is required. The FastSee data are beat with a sinusoid matching each of the BSM drive signals in order to extract the magnitude of motion and beam current fluctuations at those frequencies. Data acquisition with common synchronization is required to provide a meaningful representation of this magnitude across the multiple BPM systems of the accelerator. The TSS system provides the mechanism for accomplishing this. Each second, a time hack is sent across the TSS fiber link from the master that correlates the next second's 59 TSS messages for all BPM IOC's. A sub-second batch of FastSee data is triggered using this one-second time hack

as a reference. This assures that all BPM's in the accelerator can gather a coincident burst of FastSee position and current intensity data.

The beating sinusoid is constructed for each FastSee data acquisition burst to match the phase and frequency of the BSM drive signal. The frequencies are fixed and known. They are simply the set points for the BSM lock-in amplifiers, as listed previously. The phase angle relative to the FastSee data is dynamic and unknown. It is measured using a VMIC-3114 analog to digital converter (ADC) triggered at the initiation of the FastSee acquisition burst. The ADC's inputs are the four BSM drive signals. This ADC is part of a dedicated system that then relays, via the site network, the phase information to all BPM IOC's for construction of the beating sinusoid.

The magnitude, at each BPM, of the current and position fluctuations due to the four perturbations are then displayed graphically for accelerator staff study.

PRESENT STATUS AND FUTURE PLANS

This system is in the process of initial testing. Problems are being addressed regarding data stability. Differential data are reasonable, if not completely stable.

In the future it will be desirable to replace the VMIC-3114 ADC with dedicated similar functionality on the TSS boards. Phase measurements of the BSM drive signals will then be possible with much greater accuracy and with less software complexity.

It will also be desirable to place perturbation sources in other locations of the accelerator in addition to the injector. At a minimum, replicating the points of excitation for the pulsed beam mode 30 Hz system is desirable. This would allow direct comparison with the two systems and a more seamless interface for accelerator staff.

By beating the FastSee intensity data with a sinusoid of twice the BSM frequency detection of aperture scraping would be possible.

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