DEVELOPING MATLAB-BASED ACCELERATOR PHYSICS APPLICATION FOR THE ILSF COMMISSIONING AND OPERATION

E.Ahmadi[1], H.Ghasem[1], J.Rahighi [1]

1. Institute for research in fundamental sciences(IPM) , Iranian Light Source Facility(ILSF),   IPM, P.O. Box 19395-5746, Tehran, Iran

Abstract

The ILSF control system is supposed to operate with Epics system. The simultaneous use of Matlab Middle Layer (MML) and Accelerator Toolbox (AT) allow for parallel, high level machine control and accelerator physics application that communicate with control system via Epics via channel access. The MML has been papered for ILSF storage ring. Some high level applications are also tested in ILSF storage ring via MML.

INTRODUCTION

The ILSF control system is supposed to operate with Epics system [1]. The simultaneous use of Matlab Middle Layer (MML) and Accelerator Toolbox (AT) allow for parallel, high level machine control and accelerator physics application that communicate with control system via Epics via channel access. Although the MML software was designed to be a scripting tool for designing and testing complex algorithms predominately during physics shifts, the MML software has also migrated into machine operations. This is a departure from the more standard programming languages used in the control room and had to overcome perception problems among software engineers. However, the reliability and speed of Matlab has proven to be more than adequate for machine operations. Typical storage ring operations uses include lattice configuration save/restore, energy ramp, global orbit correction, slow orbit feedback, and insertion device compensation. The core functionality of the MML software is focused on accelerator setup. This includes orbit control, beam-based alignment, tune correction, chromaticity correction, response matrix measurement, LOCO, insertion device compensation, photon beam steering, and as a general scripting language for machine physics studies.

APPLICATION PROGRAMS

A primary reason for middle layer software is to simplify script construction and high-level application programming. Scripts rely heavily on middle layer software to perform correlated perturb/measure studies. Application programs can be dominated by user-interface software but again benefit from the middle layer for machine control and data handling. In both cases the middle layer buffers the user from detailed Channel Access calls. The middle layer also provides high-level functions for common accelerator physics tasks. Examples include:

- Dispersion function measurement
- Tune control
- Orbit control Interface
- Loco
- Other applications

DISPERSION FUNCTION MEASUREMENT

The ring dispersion is measured by changing the ring RF frequency. LOCO reads the output of BPMs for two different frequencies, and then uses self-calibrated BPM gains to determine the dispersion values in the BPM. The following formula is using to measure the dispersion function [2]:

$$\eta_{Xy} = \frac{\Delta x,y}{\Delta \delta} \tag{1}$$

$$\Delta \delta = -\frac{1}{\alpha_c}\frac{\Delta f_{rf}}{f_{rf}} \tag{2}$$

In equations (1) and (2), the parameters η_{Xy} , f_{rf} , $\Delta \delta$ and α_c are dispersion function, RF frequency, energy dispersion and momentum compaction factor respectively. Figure 1 shows the result of dispersion measuring from model. In order to online measurement of dispersion

TUNE CONTROL

To measure the tune, the strength of quadrupoles will be changed [2].

$$\Delta \vartheta = \frac{1}{4\pi} \int \beta \Delta KDS = \frac{1}{4\pi}\sum_l \beta_I \frac{\Delta I_i}{I_i} k_i l_i \tag{3}$$

In equation (3), I, l_i and k_i is the main current of the quadrupole magnet power supply, the effective length of the quadrupole and the strength of the quadrupole magnet respectively.
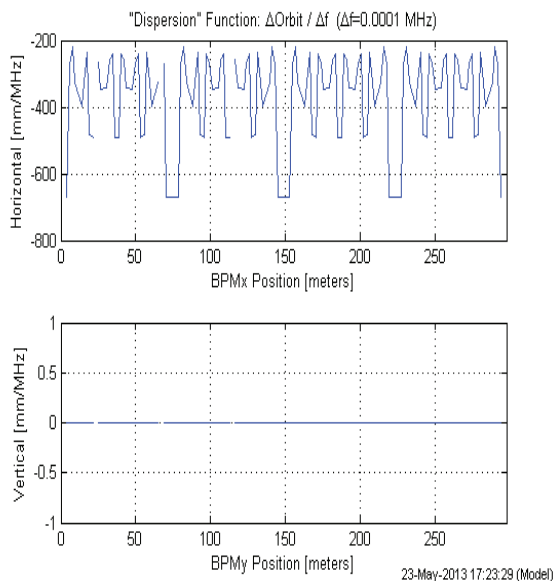
Figure 1: Measuring dispersion function using model.

For online application a GUI for tune control and measurement has been developed. Figure 2 shows a typical user interface GUI for tune control of ILSF storage ring.
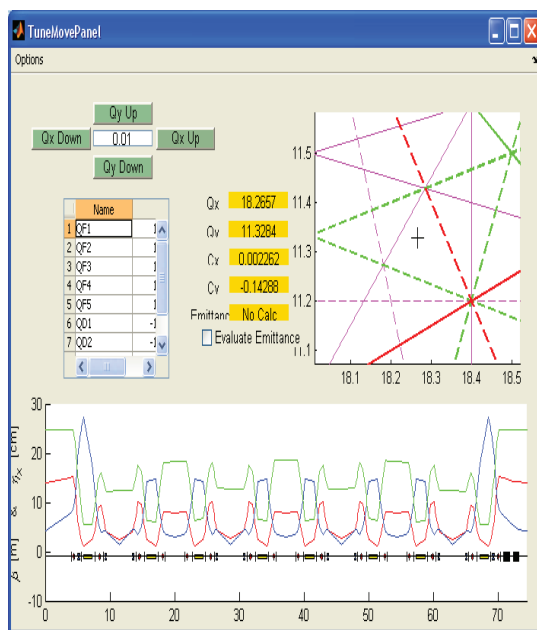

Figure 2: Tune control GUI for online application.

ORBIT CONTROL INTERFACE

Whether steering beams into collision for high-energy physics, steering photon beams in a synchrotron light source or locating beam on target in a medical application, it is essential to control the beam trajectory. The corrector-to-BPM response matrix is a vital piece of information for both orbit control and optics analysis. The response matrix can either be calculated (beta function

theory or numerical 'tracking' solutions) or measured directly on the accelerator. The basic format of the response matrix equation is [2].

$$x = R\theta$$

Where column vector x contains the orbit *shift* produced by incremental change*s* in the corrector magnets, θ. The response of BPMS to the corrector magnets is contained in R. An accelerator with m-BPMS and n-correctors produces $m \times n$ dimensional response matrix. It is worth noting that the response matrix is really a sampled version of a continuous function that describes the effect of dipole perturbations at all points in the storage ring on all other points in the storage ring. The linear response of a single dipole perturbation is the well-known closed orbit formula [3]:

$$x_0 = \theta\sqrt{\beta_k\beta_0}cos(\pi\vartheta - |\varphi_0 - \varphi_k|) + \frac{\eta_0\eta_k}{\alpha L} \qquad (4)$$

In some sense, the closed orbit formula can be thought of as the Greens function or impulse response to a δ-function corrector impulse. The impulse is in position, not time. Figure 3 shows the response matrix of BPM to correctors which has been calculated by LOCO for ILSF storage ring.
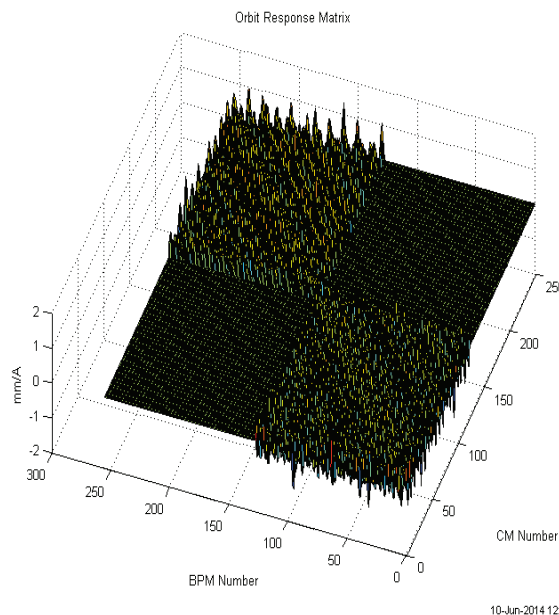

Figure 3: Response matrix of BPM to correctors using model.

LOCO

The LOCO algorithm [4] has been used by many accelerators around the world. Although the uses for LOCO vary, the most common use has been to find

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calibration errors and correct the optics functions. The light source community in particular has made extensive use of the LOCO algorithms to tightly control the beta function and coupling. Maintaining high quality beam parameters requires constant attention so a relatively large effort was put into software development for the LOCO application.

This method measures the orbit response matrix and optionally the dispersion function of the machine. The data are then fitted to a lattice model by adjusting parameters such as quadrupole and skew quadrupole strengths in the model, BPM gains and rolls, corrector gains and rolls of the measurement system. Any abnormality of the machine that affects the machine optics can then be identified. The resulting lattice model is equivalent to the real machine lattice as seen by the BPMs. Since there are usually two or more BPMs per betatron period in modern circular accelerators, the model is often a very accurate representation of the real machine. According to the fitting result, one can correct the machine lattice to the design lattice by changing the quadrupole and skew quadrupole strengths. Figure 4 shows the result of measuring and correcting of beta function by LOCO.
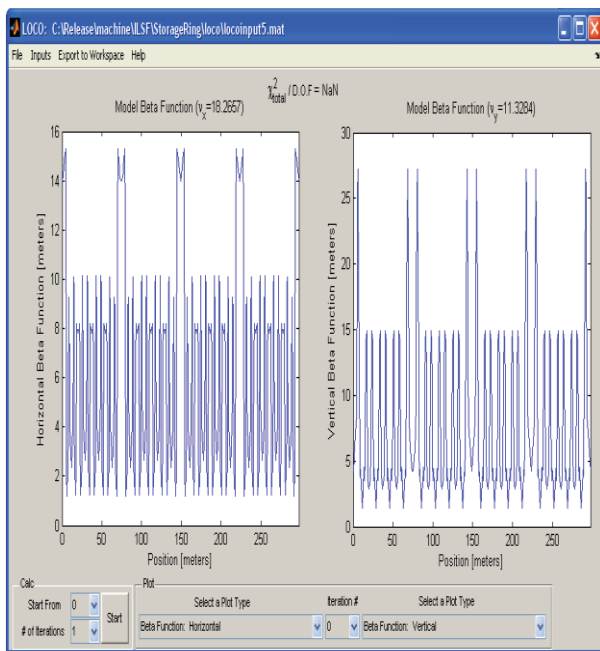

Figure 4: Beta function measurement and correction using LOCO.

OTHER APPLICATIONS

During the machine operation and commissioning the accelerator physicist will need some GUI to measure and analysis beam dynamic parameters. By using the GUI in Figure 5 which has been papered by MML, people in

the same time can measure beam parameters like dispersion, chromaticity, tune and so on.

Figure 5: A GUI for online application.

CONCLUSION

The Matlab middle layer has been papered for ILSF storage ring. Some of the high level applications like LOCO, Beam Based Alignment, and orbit control interface and chromaticity measurement has also tested via Matlab Middle Layer. In the next step, we plan to paper graphical user inter face for Beta function and dispersion measurement, chromaticity and tune correction and closed orbit correction.

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