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XAL DEVELOPMENT FOR CSNS/RCS COMMISSIONING

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Abstract

As a key component of the China Spallation Neutron Source (CSNS) Project, the Rapid Cycling Synchrotron (RCS) accumulates and accelerates the proton beam from 80MeV to 1.6GeV for extracting and striking the target with a repetition rate of 25Hz. A high level application programming framework code called XAL, based on Java Language with a well-performance online model, initially developed at the Spallation Neutron Source (SNS), has been installed as a part of control system via connection to EPICS for CSNS. Much of the applications have been initially established such as Tune Scan, Tune Monitor, Orbit Response Matrix Measurement, RCS Orbit Display, and Beta Function Measurement for preparing CSNS/RCS commissioning are showed in this paper.

INTRODUCTION

The CSNS accelerator consists of a low energy H^- Linac and high energy RCS. H^- beam with energy of 80MeV is scraped and transformed into proton beam by the carbon foil located in the injection region. After around four hundred turn accumulation, the proton beam is accelerated to 1.6GeV and then extracted to strike the target with the design power of 100kW. As a key component of CSNS, RCS consists of 4-fold symmetric structure, and each of which is constructed by a triplet cells. Table 1 shows the main parameters of RCS [1].

Table 1: Main Parameters of RCS

Parameters	Units	Values
Circumference	m	227.92
Repetition Rate	Hz	25
Average current	μA	62.5
Inj. Energy	MeV	80
Ext. Energy	GeV	1.6
Beam Power	kW	100
Quad		48
Dipole		24
Corrector		16/16
BPM		32/32
Nominal Tunes(H/V)	1	4.86/4.78

As a huge and complex accelerator, CSNS project needs a capable and well performance control system. As a high level application framework in control system, XAL is initially developed for SNS commissioning. After several years' development, and for better collaborating with other facilities and erasing the obsolete code, OPEN XAL formed out of XAL accelerator software about 5 years ago. Although XAL has capability, some modification or enhancement should be done to make the meets of the CSNS/RCS commissioning.

XAL STRUCTURE AND FEATURES

As a device-oriented accelerator application based on java language, along with jython [2] and jruby [3] scripting languages, XAL provided numerous high level application frameworks with a common look and feel. However, the core of XAL is accelerator model. The hierarchy of accelerator model is initialized with a XML file, and that consists of a lot of accelerator sequences. The accelerator sequence is comprised of many ordered nodes which represent a kind of elements that affect the beam with different path, such as magnets, RF gap, and diagnosis elements and so on. The subclass of the nodes developed to distinguish the elements, like dipoles, quadrupoles, sextupoles, BPMs, CT and so on. XAL is also has capacity in doing real time physics simulation [4], and the online model is that application, and the accelerator parameters can be easily and quickly calculated from that.

XAL provides three principal java classes which are the application adaptor, document and document window [5], and all of which are extended from their corresponding abstract parent class. The application adaptor class is the main responsible for launching the main class and also receives the call back information. The document class is responsible for reading and writing the file as well as its associated main window. The document window class is responsible for creating and managing the views. However, in order to decouple the view and the controller as required by Model-View-Controller (MVC) compliance, the document window is now an optional for the developer after the bricks application frame [5] delivered, and that facilitates the application development.

APPLICATIONS

XAL tools have been used to create more than twenty applications in CSNS. And some of them, such that PV view, have been used to monitoring CT in LEBT (Low Energy Beam Transport Line) and MEBT (Medium Energy Beam Transport Line) to measure the beam current and beam energy for CSNS/RFQ tuning. However, we only discuss part of the applications framework for CSNS/RCS commissioning presented at next.

Tune Scan Application

As described in the previous paper, The Lattice of RCS is composed of 4 symmetric fold, and the nominal beta

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tunes are designed as 4.86/4.78. Figure 1 shows the 4th order resonance line, and the red square depicts the nominal tune.

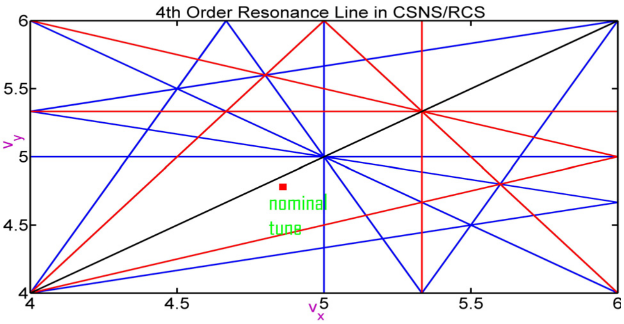

Figure 1: The nominal tune in the resonance diagram.

Some detailed research has shown that the nominal tunes are a better choice for CSNS/RCS commissioning, far away from resonance line, high efficiency in collimator, and small emmittance growth. However, it is necessary for us to develop a tune scan application for fascinating the tune setting. Besides, the detailed research reveals that the space charge effects can be weakened and compensated during one cycle due to adoption of a reasonable harmonic injection of the power system. For example, it is not difficult to modify the tune by adjusting the high order harmonics of quadrupole power system while maintaining the dipole power system.

In our simulation, the response map between tunes and quadrupoles strength were formed from a simulation code, Accelerator Toolbox (AT) [6]. The tunes table was given in a range from 4.52/4.52 to 4.98/4.98 with steps of 0.02, and the corresponding values of quadrupoles were calculated during a series of iteration. In order to get the more grids of the tune map, an optional choice was provided with a linear interpolation method. Figure 2 shows the graphical user interface of the tune scan application. The tunes increments step was designed as 0.01, and the calculated quadrupole strengths would be different if "Use Tune Offset" were selected in the application combo box. The quadrupole strength can be adjusted by summiting the figured values to virtual accelerator.

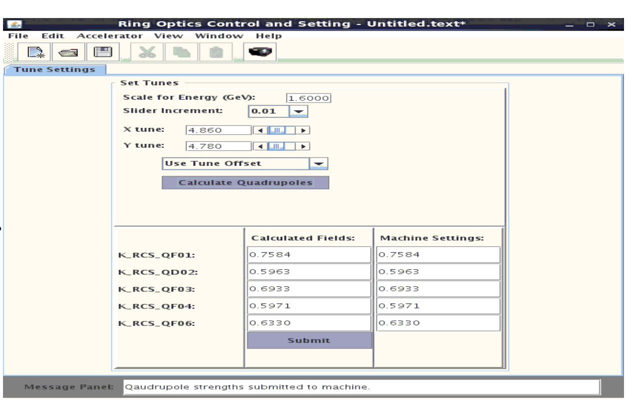

Figure 2: The tune scan application frame.

Tune Monitor Application

The tune monitor application frame was primarily developed to display the tunes in some cycle. The tunes value was calculated by Distinct FFT transformation of the BPMs turn-by-turn data. The turn-by-turn data of the BPMs in a whole cycle was provided in the format of file, and the refresh rate was around 1Hz. In this application, it is easy to get the tunes corresponding to each BPM, and it is also convenient to display tunes variation within different periods during one whole cycle by adjusting the time lag of BPM turn-by-turn data. The averaging of the tunes is a good reference for the tunes figured from each BPM. And the tune monitor application is shown in Figure 3.

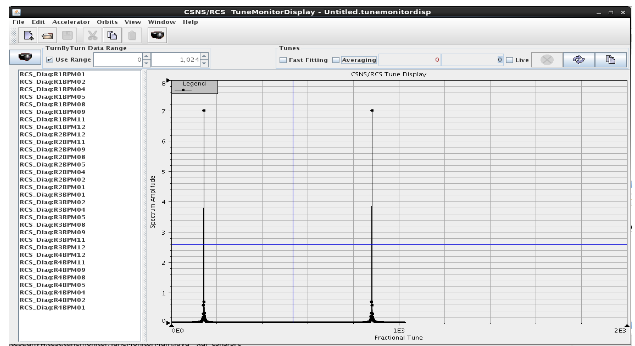

Figure 3: The tune monitor application frame.

Response Matrix Measurement Application

The application of orbit response matrix is widely used for its good performance in calibrating lattice parameters [7]. The errors from BPMs, correctors, cavities, but mainly from quadrupoles can be figured by a series of iteration to the displacements between the theoretical and experimental orbit response matrix. In this application, the BPMs and the correctors can be arbitrarily selected in the check boxes, and the initial steps of the correctors is setting as 0.2mm-mrad, and the response matrix are the slopes of the five orbit displacements. Figure 4 shows the application of response matrix measurement. And the measured response matrix data will be treated with LOCO [7] to figure the accelerator elements errors.

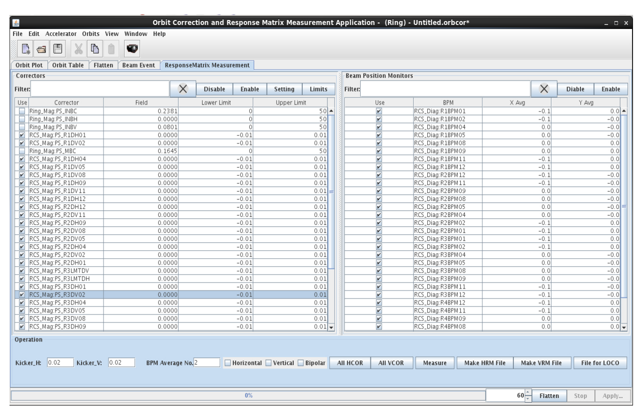

Figure 4: The response matrix measurement application.

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RCS Orbit Display Application

There are 34 BPMs locating symmetrically along the RCS ring, and two of which only work in low energy region and will be shut down when the energy of beam ramping up. 20 sets of COD data will be given as one PV during one cycle for each BPM, and each set of COD data is the average of displacements of the beam revolution around 1000 turns. As shown in Figure 5, the orbit of the RCS ring can be monitored in the whole cycle. The left part of the diagram represents 20 traces of the orbits while the right part of that represents one trace of the orbits. It is more convenient for us to monitor each trace of the COD data only if we reopen a new document and select one that we are interested in. In our simulation, the PV of that 20 sets of COD data scaled by magnet rigidity, and so each trace of all the BPMs acts in a same pattern in the diagram.

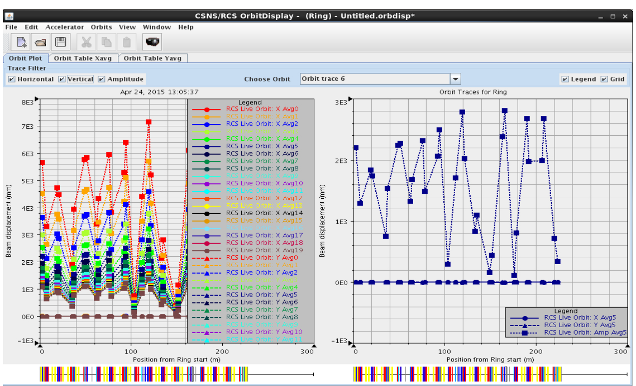

Figure 5: The RCS orbit display application frame.

RCS Optics Measurement Application

Beta Function Measurement is another vital important application for CSNS/RCS commissioning. It can be carried out by the application of the orbit response matrix [7]. However, due to quick data acquisition, turn-by-turn data analysis of the BPM samples is becoming more popular and convenience, especially for rapid cycling synchrotron. The samples collected by the turn-by-turn BPM can be constructed as a large matrix, and the column index of the matrix represents BPM index along the RCS ring while the row index of the matrix represents the turns of beam revolution. By giving a principal value analysis to the data samples, in other word, by giving singular value decomposition to the covariance matrix of the samples, the beta function can be decomposed from the two strongest modes, and this data analysis method is called Model Independent Analysis (MIA) [8]. Figure 6 represents the beta function measurement in CSNS/RCS, and in this application, the turn-by-turn BPM data is previously given in file without noise, and the file can be refreshed by a trigger signal from the cavity. The noise can be erased by previous data filtering or decomposed by the independent component analysis [9].

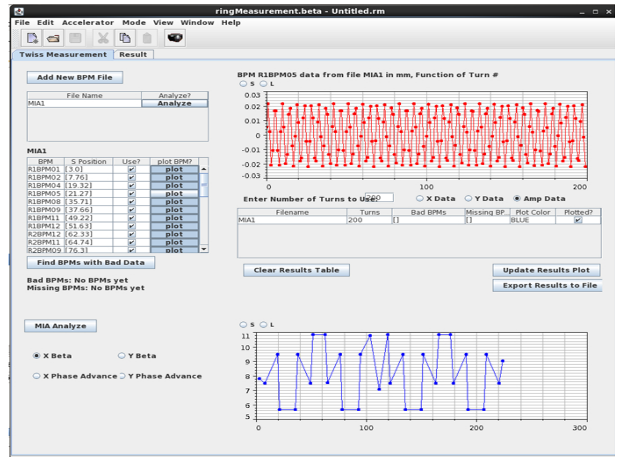

Figure 6: Beta measurement application frame.

SUMMARY

With high level application codes XAL, many applications such as tune scan, tune monitor, orbit response matrix measurement, RCS orbit monitor, and beta function measurement have been initially developed via connection to EPICS for CSNS/RCS commissioning. Some modification to XAL have been done due to the rapid cycling features of RCS, such as COD data PV and Lattice variation in one cycle. These applications have been tested in the virtual accelerator environment, and the results agree well with theoretical expectations.

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