HIGH LEVEL APPLICATIONS FOR HLS-II

K. Xuan#, G. Liu, C. Li, J. Wang, L. Wang, W. Li, J. Y. Li
National Synchrotron Radiation Laboratory, University of Science and Technology of China, Hefei, Anhui 230029, China

Abstract

The Hefei light source was overhauled beginning from 2010 and completed in the end of 2013. The new light source is renamed as HLS-II. A set of high level application tools, including physical quantity based control IOC, lattice calibration tools, orbit feedback, etc., were developed for the light source commissioning and operation. These tools have been playing important roles in the commissioning and operation of the light source. This paper reports some critical applications.

INTRODUCTION

The Hefei light source was overhauled between 2010 and 2013 using a completely new structure. The new light source is renamed as HLS-II. The HLS-II is comprised of an 800 MeV Linac and an 800 MeV storage ring. The installation of the light source components were finished in the end of 2013. The machine commissioning was started in the beginning of 2014. In January 2015, the HLS-II was brought into operation. In order to make the commissioning more effective, and achieve high performance operation, a set of high level application tools were developed based upon the Experimental Physics and Industrial Control System (EPICS) [1]. These tools have been playing important roles in both the commissioning and the operation of the HLS-II. This paper reports some of these tools and their applications.

PHYSICAL QUANTITY BASED CONTROL SYSTEM

The physical quantity based control system was first developed at the Duke FEL laboratory [2]. With necessary modifications, the HLS-II control system is developed using familiar software structure as the Duke FEL control system. The functional diagram of the control system is illustrated in Fig. 1. The HLS-II control system is comprised of three parts, IOCs for hardware controls, soft IOCs for conversions between physical and engineering quantities, and OPIs for displaying essential parameters, and running high-level tools and a number of simulation programs.

The conversion between physical and engineering quantities is realized by a soft IOC. In many cases in the light source commissioning and operation, a set of related quantities (records) need to be simultaneously processed to keep the electron beam undisturbed. This requirement is fulfilled using the EVENT mechanism of EPICS. For example, when the energy (ENG) of the storage ring is changed, a set of event with designated values are posted, and all the records related to the focusing strength of quadrupole magnets are processed as they receiving these events. This scheme has been well serving for the energy ramping and lattice adjustment of the storage ring.

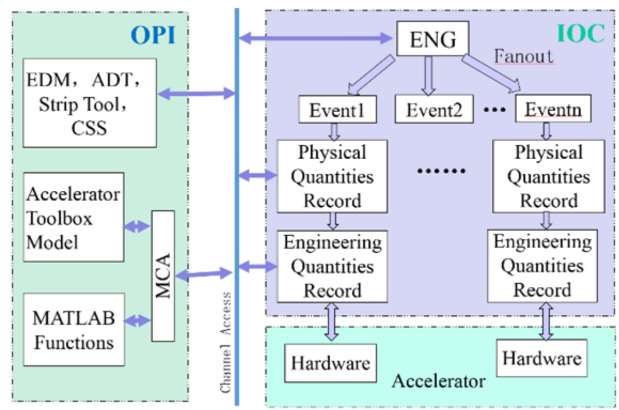

Figure 1: Functional diagram of the HLS-II control system.

The physical quantity of each component of the light source is usually divided into several parts for different purposes. For example, the total strength of a quadrupole magnet is given by

$$K = K_{design} + K_{adj} + K_{tune} + K_{comp}, \quad (1)$$

where K_{design} is the design value of that magnet, K_{adj} is used for adjustment, K_{tune} is used to change the transverse tunes, K_{comp} is used for lattice compensations. Another example is the kicking angle of an orbit corrector, its total kicking angle is composed of

$$\theta = \theta_{adj} + \theta_{feedback} + \theta_{comp}, \quad (2)$$

where θ_{adj} is used for adjustment, $\theta_{feedback}$ is used by the orbit feedback correction, and θ_{comp} is used to compensate residual field of some magnetic elements, such as undulators.

The physical quantity based control system of the HLS-II directly controls the physical quantities of the accelerator elements, including the magnetic field of various magnets, beam energy, and so on. This feature of the control system enables it to directly control the parameters of the accelerators and the electron beam. The physical quantities and related engineer quantities are automatically converted inside of the control system, and can be shared by different high level applications. This significantly improves the feasibility and effectiveness of the system. This system have been well serving the

xuanke@ustc.edu.cn

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commissioning, machine study and operation of the HLS-II light source.

LATTICE CALIBRATION AND CORRECTION

The optical parameters of the HLS-II storage ring were found very different from their design values. This is mainly caused by the alignment and field errors of various magnets. The parameter variation seriously impacts the performance of the light source. In order to eliminate this effect, we perform lattice calibration and correction using a least square method. The matlab based program, Linear optics from closed orbits (LOCO) [3], originally developed in Stanford Linear Accelerator Center (SLAC) is used for lattice fitting in the calibration. The measured response matrix using correctors and BPMs is used as the input of LOCO. Based upon the LOCO fitting, beta functions of the storage ring are corrected using K_{comp} which is discussed in previous section.

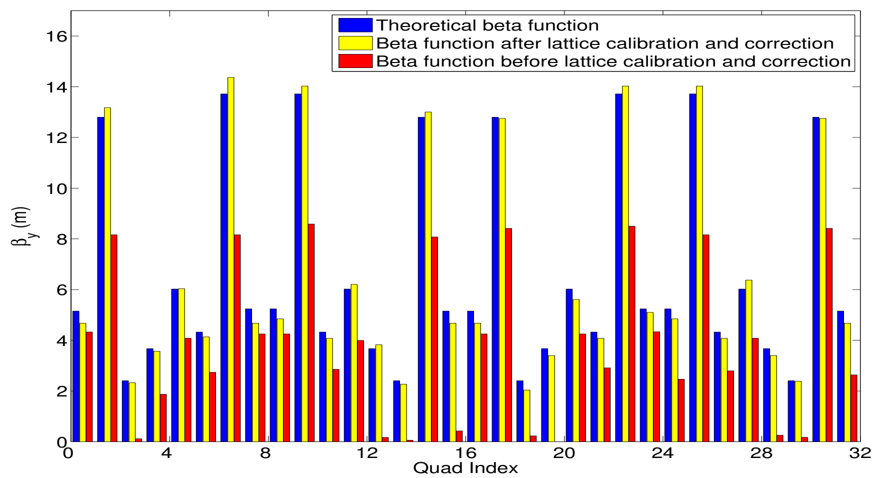

Figure 2: Design and measured vertical functions of the HLS-II storage ring.

Table 1: Beam Parameters Before and After Lattice Correction. These Parameters are Measured Using a 30 mA Electron Beam.

	Before Correction	After correction
Tune shifts	1.5%，7.3%	0.1%，0.1%
Beta beating	97.6%	6.8%
Lifetime	1.46 hrs	7.50 hrs

The beta functions of the storage ring were measured before and after the lattice correction for comparison. The measurements are based upon

$$\beta = \frac{4\pi\Delta\nu}{\Delta K l_{eff}}, \quad (3)$$

i.e. the beta function at the location a quadrupole magnet is calculated using the variation of the quadrupole strength and the measured tune shift. The measured vertical beta functions before and after the lattice correction are plotted in Fig. 2, respectively. The design vertical beta function is also plotted in the figure for comparison. This figure indicated that the beta function before the lattice correction is very different from the design value. The maximum beta beating is 97.6% comparing to the design one. After performing lattice correction, the measured beta functions are very close to the design ones. The maximum beta beating is close to our measurement accuracy (%5).

Some critical beam parameters were also measured and are listed in Table 1. The results show that the tune shift due to various errors is significantly reduced and the lifetime of the beam is increased from 1.46 hours to 7.50 hours.

This technique is also used in the lattice compensation for various insertion devices (IDs) installed in the storage ring, and achieved expected results.

The lattice calibration and correction significantly has improved the performance of the light source.

ORBIT FEEDBACK OF THE STORAGE RING

Orbit feedback of the storage ring is essential for high performance operation of the HLS-II. The orbit feedback system is comprised of four parts, the BPM system, corrector system, EPICS based control system, and a feedback program developed using matlab. The functional diagram of the system is illustrated in Fig. 3.

There 32 BPMs are installed in the storage ring. Button type electrodes are employed for beam position detection. Electronics modules manufactured by Librea are used for signal processing. 64 digital power supplies (PSs) are used to energize 32 horizontal and 32 vertical orbit

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correctors, respectively. EPICS IOCs communicate with these PSs via fibre using RS232 protocol. There is a soft IOC used for controlling feedback parameters. These parameters are controlled and monitored during operation via an EDM based OPI control panel. The feedback program is written in matlab and running in the background on a Linux computer.

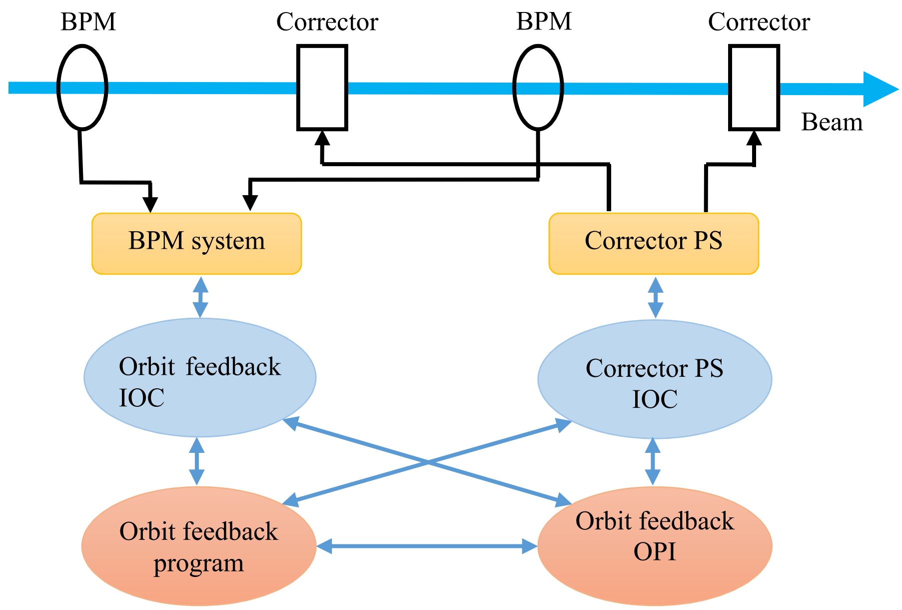

Figure 3: The functional diagram of the HLS-II orbit feedback.

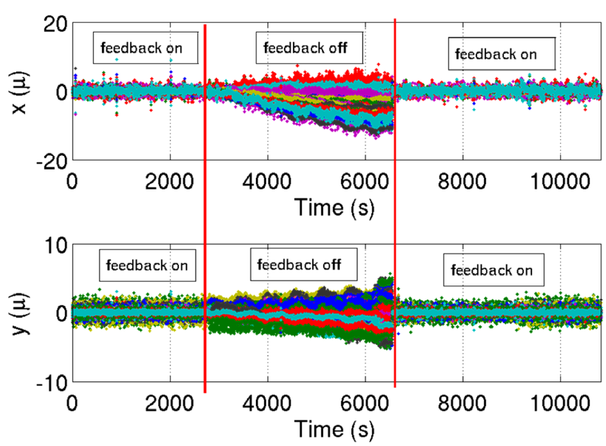

Figure 4: The HLS-II storage ring beam orbit stability with and without feedback, respectively. The values of each BPM are plotted using a designated color.

The effectiveness of the orbit feedback is test by monitoring the orbit variation with the feedback turned on and off, respectively. The results are shown in Fig. 4. During the test, the feedback is first turned on and the orbit is monitored for about 45 minutes. Then the feedback is turned off for about one hour. Finally the feedback is turned on again and the orbit is monitored for about 70 minutes. The results show that when the feedback is turned on, the orbit variation is within ±5 μm, and the orbit have significant shifts when the feedback is turned off.

SUMMARY

The physical quantity based control system of the HLS-II can be used to directly control the physical parameters of accelerators. The high level applications developed based upon this system play important roles in the light source commissioning, and are providing strong supports for stable and high performance operation of the light source.

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