The Design of LEAF Motion Control System

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Abstract. The scientific installation project (HIAF) will be undertaken by the Institute of Modern Physics of the Chinese Academy of Sciences. LEAF (Low Energy intense-highly-charged Accelerator Facility) is a pre-research project for the future large-scale scientific installation about HIAF. It was received the support of the National Major Instrument Equipment R&D Fund. In the accelerator control system, motion control plays an important role. Motion control is a branch of automation. It mainly uses servos and motors to control the position or speed of the machine. The motion control system designed in this paper is mainly used to control the gas in and out, slits motion control, beam diagnostics and other equipment. It mainly studies the hardware architecture of the motion control system, the application of EPICS in the motion control system, the HMI design of the CSS and the test of the motion control system.

1. Introduction
Low Energy intense-highly-charged ion Accelerator Facility (LEAF) is national major research equipment development project. Its construction is of great scientific significance. It can be used for nuclear astrophysics, radiation physics, etc [1]. There are four parts of it, they are superconducting ion source, high voltage platform and beam line, RFQ accelerator, and experimental terminal. Motion control system is an important part of it, mainly used for gas intake control, moving electrode, sputter control, beam slits and bias voltage control [2].

2. Structure of system
The hardware structure of this system is specifically designed as follows:

- Ion source inlet valves, slits, moving electrodes, bias, and sputter control, these equipments is controlled.
- The servo motor and driver are connected to the controlled device. Luster is used as the driver.
- The use of PLC of Beckhoff to control drives of Luster, different brands of controllers and drivers is used; this is a difficulty in this motion control.
- The brake setting of the motor adopts the on-off control method of 24V. The output signal of the Luster driver is used to brake and release the brake of the motor.
- The motion control system consists of two parts. One controller controls nine drives and motors, and one controller controls eight drives and motors.

The hardware control architecture is shown in Fig. 1.
Figure 1. Hardware architecture of LEAF motion control system

For motion control, achieving the designed accuracy requires careful research. In order to achieve this goal, data fitting methods are used to calibrate software parameter values in actual projects. For example, the slit control system designed in this paper allows it to gradually move from a stroke end to another stroke end with a certain step length [3]. At the same time, the actual movement displacement of the slit is measured with a three-dimensional laser tracker, and the tracker is recorded at each position. Value, motor displacement given value, and repeated measurement many times, the obtained data is processed offline, using the measured value as a standard, correcting the given value and read back value. The measurement, recording, and correction processes are repeated, and the motion control accuracy of the design requirements is finally achieved, so that the read-back value and the error between the given value and the measured value are within the receiving range. Due to the non-linearity of the transmission, the curve fitting method can be used for both the set point and measured values, read back values and measured values in the process of program correction.

3. Software design
The motion control hardware of LEAF is mainly used by PLC controllers of Beckhoff and Luster drivers and motors. The design of software based on EPICS architecture. IOC is run independently in the PLC controller. This can be separated from the server and run in distributed control mode. In the current design, one PLC controller connects eight drives and motors, and the other PLC controller connects nine. The GUI is designed by CSS. The GUI of the ion source gas intake control and the moving electrode, sputter control, beam slits and bias voltage control [4].

3.1 Ion source gas intake control
Ion source gas intake control is an important part of the ion source control system, and it is the precondition for the ion source to be able to beam smoothly. This system mainly includes working gas control and support gas control, including angle reference and angle read back. Motor movement, motor stop and motor reset. The movement of the motor uses absolute position control. If you encounter a problem with the drive, click the reset button to reset the drive so that you can troubleshoot. The interface design is shown in Fig. 2.
3.2 Moving electrodes and sputtering control
Moving electrode and sputtering control are important parts of LEBT control. The functions of these two parts are position reference, position read back, motor movement, stop and reset. The specific design is shown in Fig. 3.

3.3 Bias and slits control
The bias control function is also position reference, position read back, motor movement, stop and reset. However, for slit control, it is more complicated because a group of slit control is actually the relative motion of the four motors. The difference between the relative motions is the value of the slit. So it includes setting and read back of the positive and negative directions of the x axis, setting and reading of the positive and negative directions of the y axis, and the relative movement of the x axis and the relative movement of the y axis. value. The specific interface design is shown in Fig. 4 and Fig. 5.
4. Specific test
Since March 2018, motion control system of LEAF has been installed and tested. At present, 17 sets of motors have been commissioned. The hardware of on-site deployment is shown in Fig. 6.
The software is designed based on the independently running IOC by EPICS. The GUI is designed by CSS. At present, all the parameters requirements of the system control has been completed and all the functional requirements have been finished. The configuration and debugging HMI of the controller is shown in Fig. 7.

![Figure 7. The HMI of Beckhoff controller](image)

5. Summary
The optimization and detailed design of the GUI and test with the system's equipment on the next step. LEAF is a pre-study device of the front-end of the scientific device of HIAF. The study of this motion control system can provide reference for HIAF motion control design in the future.

6. Acknowledgement
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7. References
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