

NEW CONTROL SYSTEM FOR LAPECR2*

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Abstract

Lanzhou All Permanent magnet ECR ion source No.2 (LAPECR2) is the ion source for 320 kV multidiscipline research platform for highly charged ions. Its old control system has been used for nearly 12 years and some problems have been gradually exposed and affected its daily operation. A set of PLC from Beckhoff company is in charge of the control of magnet power supplies, diagnostics and motion control. EPICS and Control System Studio (CSS) as well other packages are used in this facility as the control software toolkit. Based on these state-of-the-art technologies on both hardware and software, this paper designed and implemented a new control system for LAPECR2. After about half a year of running, the new control reflects its validity and stability in this facility.

INTRODUCTION

Since built around the year of 2005, 320 kV multi-discipline research platform for highly charged ions has successfully produced and delivered ion beams with kinetic energy from several keV to MeV for many experiments such as ion-atoms/molecular collision, ion-surface interactions, low energy astrophysics [1], etc. Its operational time can amount up to 6500 hours per year. The 320 kV multi-discipline research platform for highly charged ions consists of the Lanzhou All Permanent magnet ECR ion source No.2 (LAPECR2) [2] located on 320 kV high voltage platform, an electrostatic accelerating tube, beamline and 6 experimental terminals.

After almost 12 years in operation, many problems of its old control system were gradually exposed such as the ever worse stability and reliability, high failure, poor maintainability and so on which affected heavily the daily operation of 320 kV research platform. Besides, the old control system is difficult to extend or change when the controlled devices are changed. Under this context, a plan to design and implement a new control system was proposed in 2016. The concrete goal of this plan is to design and implement a new control system for the ion source (LAPECR2) and beamline as well as experimental terminals.

In this paper, we report design and implementation of the new control system for Lanzhou All Permanent magnet ECR ion source No.2 (LAPECR2). Firstly, the structure of LAPECR2 is described briefly and control requirements are analyzed following. Secondly, design and implementation of the new control system are explained in detail. Finally, summary and future work are outlined.

LAPECR2 OVERVIEW AND CONTROL REQUIREMENTS

LAPECR2 was operated at 14.5GHz. By injecting microwave of proper power level and raw materials into vacuum chamber under appropriate magnetic field, the ions of plasma are generated. In order to extract ion beams from plasma, an electrical potential difference is needed. The max extraction high voltage is 15kV. The plasma chamber and some equipment needed to generate ion beams must be placed on high potential to enable effective extraction. After plasma is generated, a serial of measures are taken to achieve high quality ion beams. A solenoid located next to plasma chamber is used for ion beams focusing. LAPECR2 can produce multiple charge states for a given nuclide, whereas it only needs to provide a particular charge state according to a certain experiment. After strong focusing, ion beams are delivered to a 90° double focusing bending magnet, which is utilized to select the ion beam of specific charge state of the given nuclide according to the final application. Following the bending magnet are a pair of steering magnets. Following the steering magnets is a faraday cup. Next to the diagnostics is an einzel lens used to focus ion beams further. Downstream the einzel lens, there is an electric static accelerating tube. The accelerating voltage can reach up to 320kV. The mentioned equipment are all located on a high voltage platform as shown in Figure.1

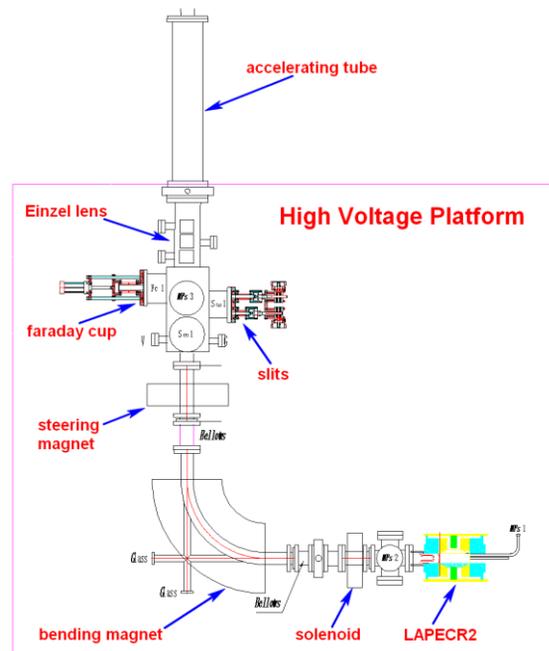


Figure 1: Layout of 320 kV high voltage platform.

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In order to operate this facility, several devices are needed to be controlled list as follow:

(1) Microwave machine

This microwave machine together with waveguide components are used to generate plasma.

(2) Power supplies

Power supplies of solenoid and bending magnet are required to be adjusted remotely. As for bias disc and extraction electrode, the situation is the same. To produce sufficient vapour of solid or metallic materials, microwave oven is used. Its power supply also needs to be adjusted remotely.

(3) Gas valves

Gas valves of working gas and supporting gas are also demanded to be accurately adjusted remotely. These gas valves are driven by two servo motors.

(4) Auxiliary devices

These contains vacuum gauges, cooling meters and beam diagnostics. Besides, relevant interlocks must be implemented to ensure high reliability.

DESIGN AND IMPLEMENTATION OF NEW CONTROL SYSTEM

In design and implementation of the new control system, we adopted PLC from Beckhoff company to finish the control of passive devices and motion control. As for software, we choosed EPICS(Experimental Physics and Industrial Control System) [3] as the integrated development framework.

Architecture of New Control System

Architecture of the new control system is shown in Figure.2.

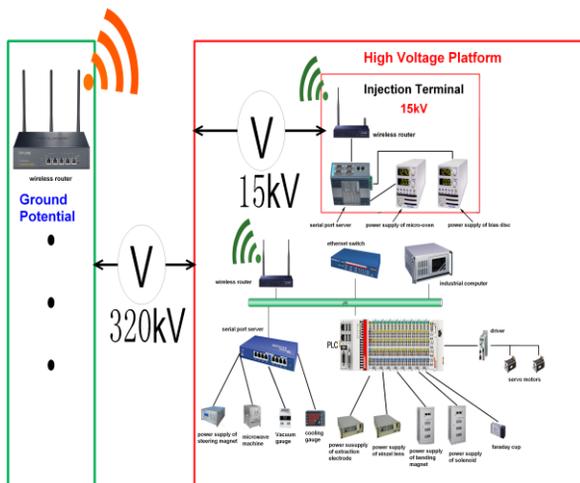


Figure 2: Diagram of control system architecture.

As is shown in Fig.2, because there are types of control interface of the controlled devices, relevant measures must be taken to unify the control interface. For example, magnet power supplies have several sorts of control interface (RS485, analog I/O) while microwave machine, vacuum gauges and cooling meters are controlled through RS232. In this context,serial port servers were used to convert serial protocols to TCP socket for data exchange

through the control network. As for those devices controlled through analog I/O and digital I/O are managed by a high performance PLC from Beckhoff company. In all, in the view of IOC, there is only one kind of control interface which is TCP socket. Thus, all devices were integrated together into the control system network in a seamless way. This makes control architecture more flexible and scalable.

Hardware Configuration

As for hardware configuration, a powerful industry computer from Advantech company running CentOS 6.6 is used as EPICS Input/Output Controller(IOC) with front-end control software running in it. This IOC integrates all devices together through control network and communicates with the outside with process variables(PV). It also manages part of interlock and human safety.

Another thing worth noting is that we used two servo motors to adjust two gas valves. These servo motors are provided with absolute positioning functionality even when they are powered off. This functionality is very useful for beam tuning because they provide the operators with precise control and quantitative reference. Besides, this functionality greatly reduce maintenance since the servo motors need self-calibration zero spot only once after installation. The drivers are also managed by the PLC through EtherCAT field bus. Also, from the view of IOC, it only needs to send control commands and receive state values of the motors and do not need to care about the details of motion control which is done by the PLC.Hardware configuration is shown in Figure.3.

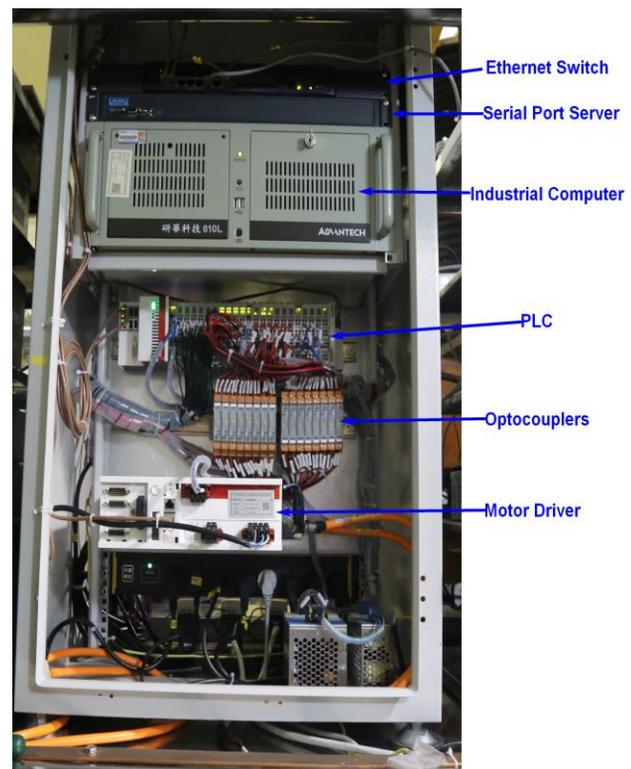


Figure 3: Hardware configuration.

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Operator Interface

As for the interactive GUI, we chose Control System Studio(CSS)[4] which is a cross platform and support rapid development. Besides, it is easy of operation and maintenance. This GUI has a main panel and three sub panels. General running status are shown in main panel. Operation and monitoring is done detailly in the “Adjust Beam” sub panel. The “Spectrum” sub panel is used to plot spectrogram and select the needed ion beam. The “Adjust Beam” panel is shown in Figure.4. and the “Spectrum” panel is illustrated in Figure.5.



Figure 4: The “Adjust Beam” panel.

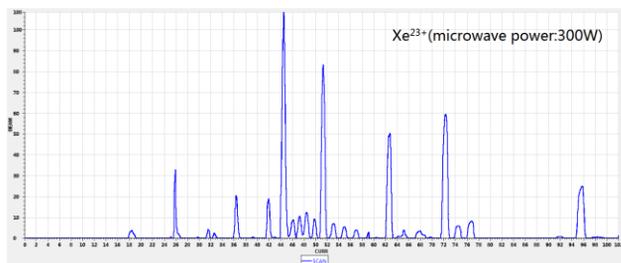


Figure 5: The “Spectrum” panel.

This GUI run on another industrial computer with Windows operating system located in the control room which is placed on the ground potential. As mentioned above, we used wireless communication method. We used three wireless routers with one master router on the ground potential and two slave routers placed on two high voltage potentials as shown in Figure 2.

Interlocks

During the operation of LAPECR2, malfunction or undesirable operation state can hardly be avoided which may be harmful to controlled devices. In this context, interlock mechanism must be implemented to ensure good operational performance. If the situation is going worse, the interlock mechanism will take effect to shutdown relevant devices. The interlocks are list in Table 1.

Table 1: Interlocks of LAPECR2

Trigger Source	Protection
Injection Vacuum	Microwave machine Extraction high voltage
Extraction Vacuum	Microwave machine Extraction high voltage
Cooling pressure	Microwave machine
Cooling temperature	Microwave machine
Cooling flux	Microwave machine

The trigger sources use “OR” logic. This implies that any trigger source can trigger interlocks.

The 320kV high voltage platform was installed in a closed hall with a door to enter. The door with a key signal. This key signal is gathered by another PLC located on ground potential. This PLC is in charge of human safety. Normally when LAPECR2 is in operation, nobody is allowed to enter the hall. If the door is opened, both the microwave machine and the high voltage power supplies are cut off to protect human from been hurt.

SUMMARY AND FUTURE WORK

In order to build a new control system of good quality, control requirements were analyzed in detail. Based on EPICS and PLC, the new control system for LAPECR2 was designed and implemented. Hardware and software resources were integrated to be a whole in the new control system which may provide some substantial reference for future work.

Since its completion in September 2016, the new control system has enabled successful operation of LAPECR2 and reflects its validity. The successful application of EPICS reflects its power and validity in LAPECR2.

In the future, we will implement new control system for the beamline and 6 experimental terminals. Based on EPICS and PLC, this will be favourable and smooth.

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