Application of EPICS based I&C in TRAP, KAHIF, and KoHLT-EB

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1. Introduction

An Instrumentation and Control (I&C) system must be fundamentally constructed in order to control and monitor an experimental apparatus or facility. This is because each experimental apparatus and facility serves a distinct purpose in its design and utilization. Using the same I&C development framework is advantageous for maintenance, and once a solution has been created, it can be readily and quickly adapted to other apparatus or facilities with minimal effort. This paper tries to show that the Experimental Physics and Industrial Control System (EPICS) can be used in different situations by showing how it can be used in two facilities that are already up and running and an apparatus that is still being made.

2. Considerations on the I&C of TRAP, KoHLT-EB, and KAHIF

The Nuclear Physics Application Research Division of KAERI is developing various ion sources, including the Neutral Beam Injection (NBI) system and compact neutron generators, and Two Region Arc Plasma (TRAP) is one of them. It also runs a heavy ion beam irradiation facility for the development and testing of fusion materials, as well as a high-heat load test facility utilizing electron beams for the development and testing of plasma-facing components (PFCs). Each I&C is uniquely implemented according to its features. This section describes the differences in the methods applied in each apparatus and facility

2.1 Characteristics for TRAP I&C

TRAP is a large-area ion source under development to advance the fundamental research of negative ion sources for nuclear fusion NBI systems. This ion source is composed of a plasma discharge chamber and a beam extraction system. The beam extraction system has been recently assembled and is currently undergoing testing [1,2]. The basic performance test using plasma discharge chamber has been completed, and we are currently preparing to conduct the performance test with the extraction chamber installed. The characteristics that I&C should have are that they must be able to easily respond to any additional or changing elements that arise during the development process. Table I lists the instruments needed for control, and Fig 1 is a simplified power connection schematic prepared for the experimental setup of the TRAP ion source, showing the correlation of power during operation.

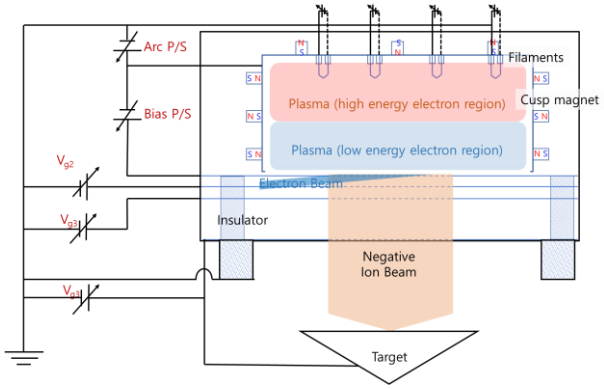

Fig. 1. Power connection schematic of the TRAP ion source experimental setup.

Table I: I&C instruments for TRAP

Key Function	Device(specification)			Interface
Power Supply	Filament	30V/400A	8ea	Modbus RTU
	Arc	20V/1000A 40V/1000A	3ea 1ea	RS-485
Vacuum Monitor Control	Vacuum Monitor	TPG-262	2ea	RS-232
	Gas Control	MKS type 247		RS-485
Beam Extraction Control	Bias	30V/400A		Modbus RTU
	G2	2kV/2A		RS-232
	G3	10kV/500mA		RS-485

2.2 Characteristics for KAHIF

In 2018, KAERI Heavy Ion Irradiation Facility (KAHIF), formerly known as the Tokai Radioactive Ion accelerator Complex (TRIAC), transferred to KAERI and completed its reassembly. [3][4] Previously, it used a LabView-based I&C system operating in a Windows environment, but the lack of integration between all instruments and the end of support for certain components made it imperative to switch to a new I&C. [4] It was decided to the port the I&C to an EPICS-based I&C while avoiding replacing sub-hardware related to the control of the I&C as much as possible,

and the I&C was also completed in 2018. In 2022, it was decided to use the facility for ion irradiation of fusion materials. I&C's functionality has been enhanced to include ion irradiation capabilities that reflect user requirements, such as the need for specimen heating. Today, it functions as a facility capable of irradiating helium, argon, and iron ions. Fig 2 shows the relationship of the instruments involved in the control of TRIAC, and Table II lists the instruments required for the control of KAHIF.

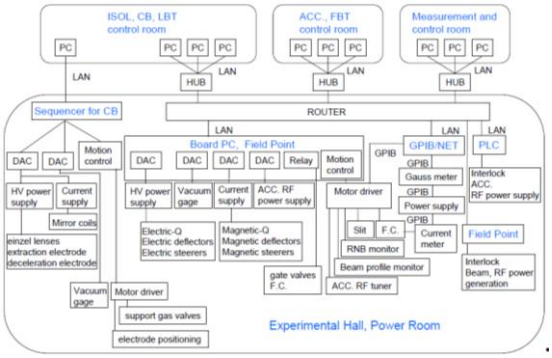

Fig. 2. Diagram of the TRIAC control

Table II: I&C instruments for KAHIF

Key Function	TRIAC	KAHIF
Vacuum Control Monitor	OMRON PLC FieldPoint/Panel	OMRON PLC Serial to Ethernet
Coolant Control Monitor		LS PLC
CB Control Monitor	YOKOGAWA PLC LabView	YOKOGAWA PLC
Magnet Control	GPIB to Ethernet LabView	GPIB to Ethernet
EINZEL Control Monitor	PCI LabView	PXI
Beam Monitor	Panel with R8340	GPIB to Ethernet with R8340
Heater Control Monitor		RS-485 with SP540
Interlock	OMRON PLC	LS PLC

2.3 Characteristics for KoHLT-EB

Korea Heat Load Test using Electron Beam (KoHLT-EB), a test facility for the development of fusion plasma-facing components, was completed in 2016. [5] The system that extracts the electron beam from the electron beam gun and allows for uniform thermal loading on the mock-up at the bottom via the beam scan system was built using Siemens' PLC, and the I&C for monitoring the temperature and flow rate of the mock-up and test chamber was completed at the same time as listed in Table III. To satisfy the advanced needs, the I&C was replaced by a new I&C capable of high-speed measurement and processing based on FPGA. In this case, the entire hardware platform of the I&C was replaced.

Table III: I&C for KoHLT-EB

Key Function	Device(specification)			Radius (cm)
Temperature Monitor	mockup	K-type TC	7ea	FPGA
	mockup surface	Pyrometer	2ea	RS-232
	coolant	K-type TC	10ea	FPGA
Pressure Monitor	Pressure	Wise P316	2ea	FPGA
	Differential	Yokogawa EIA 110A	2ea	FPGA
Flow Monitor	coolant	RHE27	2ea	FPGA Modbus
		Aichi	5ea	RS-485
Vacuum Control Monitor	control	Pfeiffer valve	1ea	Modbus
	monitor	TPG-261	3ea	RS-232

3. Conclusions

In the preceding section, we analyzed three distinct application cases: sequentially adjusting I&C to align with the apparatus under construction, transferring the top-level interface of the current I&C to a new system, and ultimately, substituting the existing I&C with a whole new system. These examples illustrate the flexibility and adaptability of EPICS based I&C across many contexts. I&C are essential for developing new experimental apparatuses or operating facilities. EPICS is an open-source platform for I&C development that facilitates the integration of various instruments. Moreover, utilizing identical development tools facilitates the simultaneous maintenance and management of many testing facilities and apparatuses.

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