THE CONTROL SYSTEM OF THE SDUV-FEL TEST FACLILITY

J. G.Ding, S.M.Hu, G.Y.Jiang, H.F.Miao, H.Zhao, H.J.Zhu, SINAP, Shanghai 201800, PRC

Abstract

Shanghai Deep Ultra-Violet Free Electron Laser (SDUV-FEL) test facility was integrated to test the FEL key technologies. A number of SASE and seeded FEL experiments have been carried out at the facility and progress have been archived in the past year [1][2]. In this paper, detailed description of the SDUV-FEL control system is presented. Solutions for the device controls, networking, timing and machine protection systems are reported and control software is introduced as well.

INTRODUCTION

The SDUV-FEL facility is an integrated multi-purpose test bed for FEL principles. The facility is composed of two parts of Linac and Undulator. The linac part was upgraded from an existed 100 MeV linear electron accelerator with hardware additions and modification, composed of a low emittance photocathode injector, five S-band linac sections, one bunch compressor (BC). The undulator part is the SDUV-FEL experimental area, including seeded laser, EMU type and PMU type modulators with moveable gaps, dispersive sections, small radiators with only a few periods and optical diagnostics system.

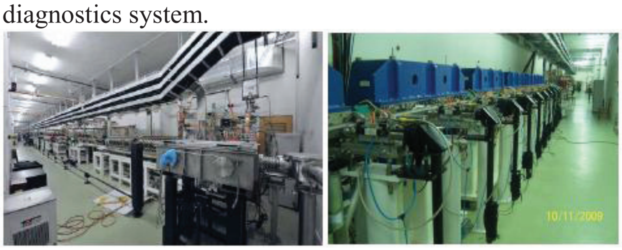

Figure 1: Inside the SDUV-FEL tunnel (left:Linac part, right:Undulator part).

The SDUV-FEL control system was developed for the facility operations and beam commissioning, which is employed Ethernet-based distributed architecture. The Experimental Physics and Industrial Control System (EPICS) toolkit was used for the control system development [3]. The system is employed Ethernet-based distributed architecture, consists of three layers of Operating Interface (OPI), Input/Output Controller (IOC), and Ethernet linking the OPI and IOC layers. OPI computers run GUI engineer tools for device monitor and operation, and execute model-based high level physics programs for beam commissioning. Several distributed IOCs run the EPICS core to implement process control by the EPICS runtime databases. Database records describe the details of the process control of I/O channels they are event or periodical triggered to process by an internal scanner. OPI routines access I/O channels in the IOCs via the TCP/IP-based Channel Access (CA) protocol. IOC receives and executes instructions from OPIs and gives responses to the OPI queries.

SYSTEM IMPLEMENTATION

Input/Output Controller

IOC controllers are the key components of the control system based on EPICS. To meet the demands of reliability, flexibility and availability, IOCs are mainly VME bus systems equipped with Emerson MVME-2300, MVME-3100, MVME-5500 PowerPC boards and I/O cards, and running the wingRiver vxWorks or the RTEMS real-time operating system. Some Linux-embedded industry PC with multiple serial ports and Ethernet interfaces are used to communicate with the RS232 or Ethernet attached devices.

Six VME IOCs and four Linux-embeded IOCs are used on the SDUV-FEL control system. When a VME IOC is booted, it downloads the operating system, the EPICS base core and runtime databases from a boot server and starts running. An embeded IOC stores all software in its flash ROM, EPICS application starts process when it powers up.

Servers and Console

One IBM Server is used as the EPICS server to provide services of FTP for IOC software download, NTP for time synchronization, NIS for user account management, NFS for file sharing, etc. The EPICS toolkit, utilities and tools for beam commissioning are installed in the server and shared by all consoles. All OPI computers are logon to the EPICS server for the control system operations

Equipment Interface

Table 1: Equipment and Interface

Equipment	Number	Control interface
Power supply	138	DeviceNet, GPIB, Serial
Modulator	3	Ethernet, DCM
Vacuum gauge controller	11	RS232
Ion Pump power supply	31	RS232
Shifter	4	DCM
Interlock system	1	Ethernet
Undulator	4	RS232, Ethernet
Microwave Amplifier	3	Direct I/O

As shown in Table 1, SDUV-FEL includes a considerable number of conventional systems and equipment with different interfaces to be controlled. Equipment interfaces are mainly direct I/O (AD/DA, digital I/O) controlled, serial lines (RS232/485), field bus

ISBN 978-3-95450-122-9

(DeviceNet), Ethernet and the DCM communication which is a specific solution of Allen-Bradley products. Special solutions are required for different equipment interfaces and communication protocols. For those devices of the original linac, original solutions were remained with less modification [4]. Many new added devices have serial interface, serial-to-Ethernet communication servers manufactured by MOXA [5] are employed to transform serial communication to Ethernet. "Ethernet as field bus" is mostly used in the SDUV-FEL control system. Table 1 lists the controlled equipments and their interfaces.

Magnet Power Supply Control

Because the magnet power supplies in the SDUV-FEL facility were manufactured in different period, they have different interfaces for remote control. Power supplies of the original Linac system used direct analog and digital I/O interface, DeviceNet field bus was adopted for the remote operation. Six local power supply controllers were developed addressed from 00 to 06, they each consists of several analog and digital I/O modules, and a communication module. At the VME side, a DeviceNet scanner is configured toreads out power supply status from the local controllers periodically [6] and sends user operations to the local controller.

Most of the power supplies are full digitally regulated by a built-in SINAP-designed digital power supply controller with DSP and FPGA technologies. A serial link with a pair of plastic optical fiber interface is used for remote operation. A communication server is employed to transform RS232 protocol to Ethernet. An opto-electrical circuit is applied between the serial-to-Ethernet server port and the power supply.

In addition, there is an Agilent 6682 power supply which can be remote programmed by SCPI language over its GPIB interface. A GPIB-RS232 converter and a communication server are employed here for IOC operating the power supply via Ethernet.

Figure 2 shows the solution of the SDUV-FEL power supply control system.

Vacuum Monitoring and Protection

All vacuum gauge controllers and pump power supplies in the SUV-FEL facility equipped with RS232 interface for remote monitor and operation. Each controller is connected to a RS232 port of a serial-to-Ethernet server, thus IOC accesses gauge controllers and pump power supplies via Ethernet.

Each gauge controller controls two vacuum gauges and has eight setpoint output. Two setpoint outputs are defined for one gauge, one called warning output to stop beam, the other called alarming output for vacuum protection that means to close valves of the vacuum leak area. A PLC system execute Ladder logics to implement vacuum operation which communicates with upper IOC using its Ethernet module.

RF Control

The SDUV-FEL has three modulators and Klystrons separately local controlled by Programmable Logic Controller (PLC) systems of an Omron CS1 PLC, an AB SLC-500 PLC and a Siemens S3/700 PLC. The Omron and Siemens PLC both equipped with a Ethernet module for IOC access. The AB PLC links to the IOC with a pair of specific Direct-Communication-Module (DCM) at both PLC and VME/IOC side.

The control system uses another SLC-500 PLC for shifter control which includes special modules for the stepper motor control.

In addition, several VME bus direct I/O boards are employed to control other RF devices.

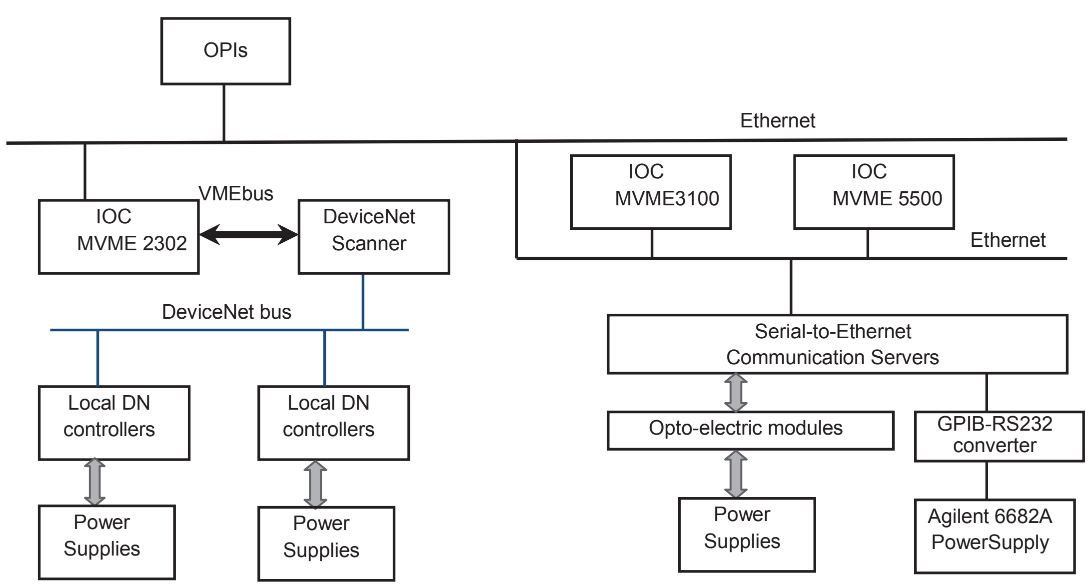

Figure 2: Layout of the SDUV-FEL power supply control system.

Undulator Gap Adjustment

Four undulators are designed to be movable for gap adjustment. Two of them are local controlled by Siemens S3/700 PLC with stepper motor controllers and the others are local controlled by intelligent motion controllers. The PLC systems and the intelligent controllers are linked to LAN, the Linux-embeded IOCs talk to them by TCP/IP.

Timing and Interlock

The timing system consists of two 8 channel BNC 555 digital delay-pulse generators providing triggers to the injector, microwave amplifier, modulators, beam diagnostics system and optical diagnostics system as well. There is a laser synchronization system at SDUV-FEL which is operated independently.

A specific circuit was designed to implement machine protection and safety interlock functions. It collects inputs from the RF gun, modulators, vacuum system, gate access system, and utilities, and decides to enable/disable trigger signals of the delay-pulse generators output to the devices.

Network

The control network was independent from the SINAP campus network. The backbone of the control system is a gigabit network. It is small scale LAN composed of one gigabit switch in the control room and two fast/gigabit Ethernet switches located at the technical halls. There are about 40 Ethernet ports.

CONTROL SOFTWARE

For different equipment interfaces and communication protocols, specific device support and drivers are necessary to make the device to be controlled by EPICS. Most device support and drivers adopted in the control system were contributed by the EPICS community. For example, streamDevice [7] and asynDriver [8] were used to Ethernet attached devices and serial asynchronous communication devices, the former was developed and supported by Dirk Zimoch of PSI, Switzerland, the latter by Mark Rivers of Chicago University. The EPICS Allen Bradley driver and device support for the DCM communication [9] was developed by Marty Kraimer, ANL,USA. The NetDev driver for OMRON PLC control was provided by KEK, Japan [10]. In addition, some new device support and drivers were written.

There are about 6,000 database records distributed running over the IOCs in the control system. A set of GUI operation screen were designed via Editor/Display manager (EDM) tools to access the components of the facility, and application software were developed for beam commissioning. Also PLC ladder logics were programmed for device local control. Figure 3 shows the operator interface for the undulator gap adjustment.

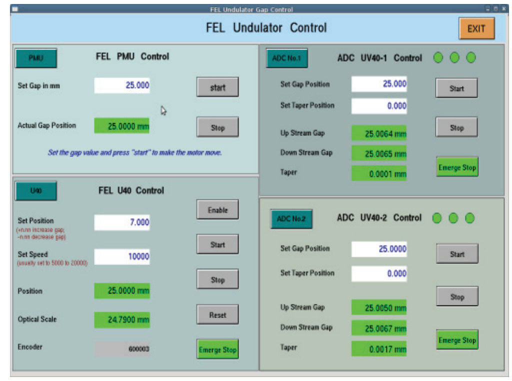

Figure 3: Operator interface for undulator gap adjustment.

CONCLUSIONS

An EPICS-based control system for the SDUV-FEL test facility has been developed at SINAP and delivered to operation. With the layered architecture of OPI, IOC and Ethernet, the control system was constructed as a fully distributed control system with advanced features of extensible and maintainable.

Several types of embedded IOC system based on Linux, Rtems and vxWorks platform were developed and successfully applied for device control solutions. In the past years, the SDUV-FEL control system has upgraded and reconfigured several times following the configuration changes of the facility for different FEL experiment purposes. Good performance has been demonstrated the SASE, ECHO and HGHG FEL experiments.

REFERENCES

[1] Z.T.Zhao, D.Wang, “Progress in the SDUV-FEL and Development of X-ray FELs in Shanghai”, FEL’10, August, 2010, Malmo, Sweden, p.23(2010),.
[2] Z.T.Zhao, D.Wang, et al. Nature Photonics, 6(2012)360.
[3] EPICS home page: http://www.aps.anl.gov/epics.
[4] M.R.Kraimer, B.Delesio, S.Allision, “EPICS Allen Bradley driver and device support”, ANL, USA, 1999.
[5] J.G. Ding, L.F. Zheng, et al, Nucl. Elec. and Det.Tech. 26(2006) 36.
[6] Moxa Technologies Co. Ltd. “NP5600 series user’s manual 5th edition”, 2004.
[7] J.T. Li, L.F. Zhen, et al. Nucl. Tech. 28(2005) 729.
[8] D. Zimoch, “StreamDevice 2.0: A multi-purpose character driver for EPICS 3.14”, PSI, Switzerland, 2003.
[9] M.R. Kraimer, M.Rivers, et al. “EPICS:Asynchronous driver support”, Icalepcs 2009, Oct 2009, Geneva, Switzerland, PO2.074-5.
[10] J.Odagiri, J.Chiba, et al. “EPICS Device/driver support modules for network-based intelligent controllers”, Icalepcs 2003, Oct 2003, Gyeongiu, Korea, p.494.

ISBN 978-3-95450-122-9