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UPGRADE TO THE EPICS CONTROL SYSTEM AT THE ARGONNE WAKEFIELD ACCELERATOR TEST FACILITY*

W. Liu†, C. Whiteford, E. E. Wisniewski, G. Ha, J. H. Shao, J. G. Power, P. Piot, D. S. Doran
High Energy Physics Division, Argonne National Lab
G. Shen, A. Johnson, J. Byrd
Advanced Photo Source, Argonne National Lab

Abstract

The Argonne Wakefiled Accelerator (AWA)¬ Test Facility has used a completely homebrewed, MS Windows based control system for the last 20 years. In an effort to modernize the control system and prepare for an active machine learning program, the AWA will work with the Advanced Photon Source (APS) controls group to upgrade its control system to EPICS. The EPICS control system is expected to facilitate collaborations and support the future growth of AWA. An overview of the previous AWA control and data acquisition system is presented, along with a vision and path for completing the EPICS upgrade.

INTRODUCTION

The current AWA control and data acquisition system is upgraded from the old CAMAC hardware-based system. It's a centralized system started with two computers working independently. One is responsible for control and the other one is responsible for data acquisition. We used all commercial hardware(HW) and the software(SW) is in-house programs written in C/C++ using Microsoft Visual Studio. The GUIs are programmed with Microsoft Foundation Class.

* Work supported by the US Department of Energy, Office of Science
† wmliu@anl.gov

The system grows with the expansion of the facility. As shown in Fig. 1, it is now more or less a distributed system with many different hardware from different vendors. The original centralized configuration makes it harder and harder to maintain. It is time to adapt the concept of distributed control system and EPICS [1] is the perfect choice.

This upgrade will make it easier for the future growth of AWA facility and its control hardware upgrade. Also by upgrade with EPICS will make AWA facility control and data acquisition system compatible with most of other accelerator facilities around the world and allow AWA to carry out AI/ML projects with higher efficiency and thus be more productive.

THE CURRENT AWA CONTROL SYSTEM

As shown in Fig. 1, the AWA control and data acquisition system mainly consist of three PCs (Ctrl PC, DAQ PC and LLRF Ctrl PC) in the control room and connects to other hardware via ethernet, PXI bus, serial, and analog links; a PXE boot server on the bunker roof serves two new BiRa power supply systems and some Raspberry Pis added in recently.

The three PCs in the control room are all MS Windows machines. The control and DA programs running in these three PCs communicate with each other through TCP/IP or COM (Common Object Model) to get the job done

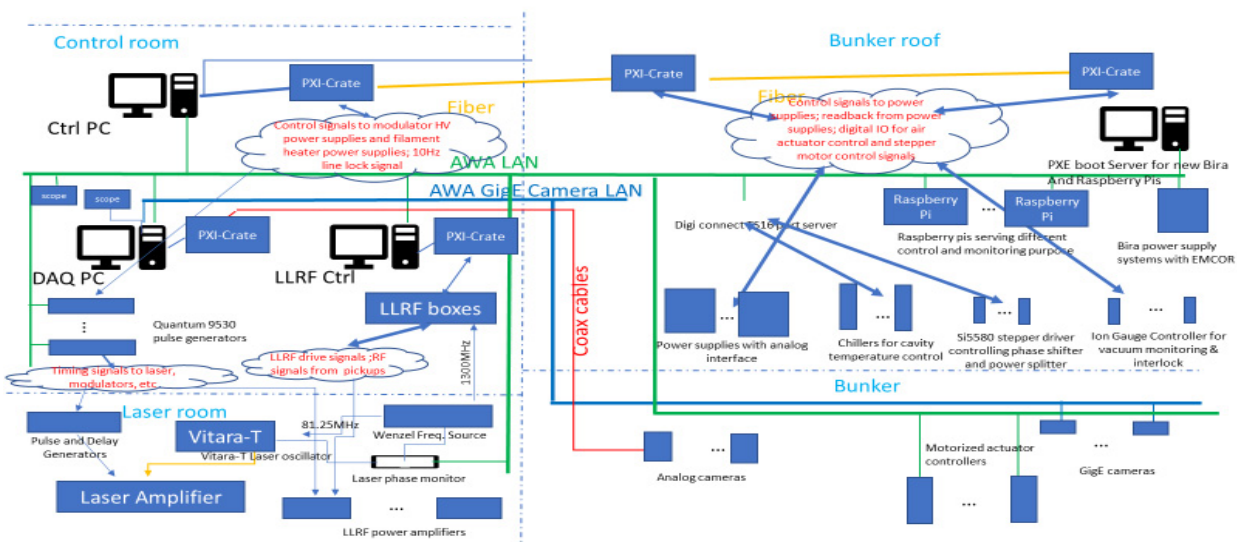

Figure 1: AWA control and DA system topology.

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Control PC

The Control PC is used to control and monitor most of the accelerator HW and hosts the control system SW and also serves as the single AWA operator station.

The control PC is a MS Windows machine which controls and monitors most of the HW through ADC, DAC, DIO and RS232 serial communications

As shown in Fig. 2, the control PC has 3 PXI crates connected PXI crate#1 resides in the control room with the control PC while the other two are in racks on top of the bunker roof. Crate#1 connected to the control PC via NI-MXI PCI-e/PCI bridge interface card and cable. Crate #2 and #3 are daisy chained to crate#1. The control HW in each crate are listed as follows. Inside these crates, we have a total of 6 • KineticSystems CP266 (+/-10V DACs, 32 or 64 channels) for controlling klystron filament heaters, Klystron High Voltage Power supplies, LLRF drive level), AWA home-made bipolar DC power supplies and other commercial power supplies with analog interface. We also have a total of 6 KineticSystems CP213 (+/-10V analog monitor, 32 or 64 channels) for monitoring klystron filament heater and other analog DC signals from all other instruments with analog interface. Digital IO channels are used for controlling laser blockers on laser splitter table for bunch train configurations, air actuators, interlock signal monitoring and controlling.

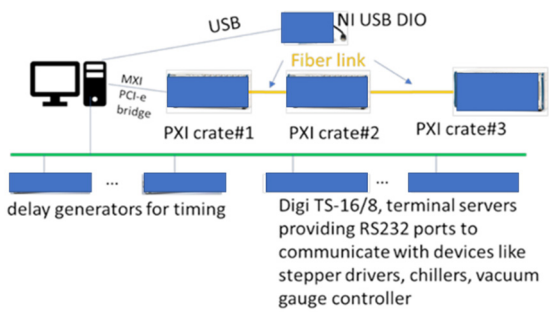

Figure 2: Hardware directly connected to control PC.

The SWs running in the Control PC are:

- AWAInterlock: A SW program which monitor and control the interlock system. (AWA interlock needs to be reconfigured based on the needs of experiment). It will log interlock events into AWA ELOG
- AWAHWI: (AWA HW Interface): A SW program directly works with CP266, CP213, USB6501, and PXI6515. It provides shared memories and a COM (Component Object Model) interface for other SW programs to interact with. It has its own GUI, but operators usually don't use it directly.
- AWASMC (AWA Stepper Motor Control): A SW program talks to Si5580 stepper drivers and PXI 7330 stepper motor controller. It provides a COM interface for other SW program to access and control steppers motors. It has its own GUI, but operators are not encouraged to use it directly.
- AWAChillerCtrl: A SW program talks to chillers using serial communications through the Port Servers. It doesn't interact with other Software.
- AWABeamline: It is the major interface which operator use to control AWA beamline. It communicates with AWAHWI through COM interface and the shared memories. It also communicates with AWASMC through COM interface. It talks with BiRa power supply control Software running in Raspberry Pi or BiRa digital control interface module with TCPIP communications. It also provides a TCPIP server to allow scripting languages like python to gain access to allowed magnets or actuators. It also provides interface to allow operator to change timing signals and to control modulator and klystron settings.
- AWARFPhaseCtrl: A SW program talks to LLRF Control computer and AWABeamline to provide operator a unified interface for controlling the RF phases of AWA beamline.

Data Acquisition PC

The Data Acquisition PC (or DAQ PC) is used to control and monitor the DAQ hardware and also serves as the single AWA DAQ station where the scientist collects data for his experiment. Hardware connected to DAQ PC are listed as follow.

- NI PXI framegrabber: for YAG image acquisition using old analog cameras.
- BlackFly GigE Cameras: For YAG image acquisition
- Linear actuators on laser splitter table: for delay adjustment between bunches.
- NewPort linear stage controller
- New Focus multi axis stepper driver for laser mirror control
- NI USB-6501: digital IO for data acquisition sync signals generation
- Lecroy Scopes for ICT signal (one with GPIB, the other with LAN)
- Si5580 stepper motor controller
- STAC5 stepper motor controllers

This DAQ PC is the major interface which facility users use to acquire data for their experiments. The major programs running in this computer are:

- AWANIFrameGrabber: A SW program for taking camera data from analog cameras. It provides COM interface for other SW programs or python script to call and control the data taking.
- AWAPGCamera: A SW program made for taking data from PointGrey GigE cameras. It also provides COM interface for other SW programs or python script to interact with.
- AWAVScope: A virtual scope SW program to download scope trace from ICT monitoring scope. It can work together frame grabber or GigE cameras to do synchronized data acquisition.
- DIOCtrl: A SW program work with the above 3 and NI USB-6501 to synchronize data acquisition.

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The user can also use python and/or Matlab to interact with the above programs to accomplish automatic data acquisition.

LLRF Control PC

The LLRF (Low Level RF) control PC was added to the system when our facility expanded from two klystrons into four klystrons. It has only one PXI crate connected to it. In that PXI crate, there is one NI PXI5105 and five NI PXI5104.

- NI PXI5105 is a signal digitizer and we use it for IQ sampling of LLRF 10 MHz IF signals to measure the phase and magnitude of cavity pickup signals.
- The five NI PXI5104 are signal generators for LLRF 10 MHz IF signal generations and we use them to control the phase of klystrons.

There are only two SW programs running on this PC.

- AWALLRFCtrl: A SW program controls the signal generators to control the phase of LLRF signals. It has a GUI but we generally don't control them directly here. Most of the controls are done from control computer over TCP/IP protocol. It provides COM interface for other SW program to access the control of LLRF signals.
- AWALLRFMonitor: A SW program works with PXi-5105 to do IQ sampling to measure RF phases and doing PID feedback control through COM interface of AWALLRFCtrl. It is also listening on a TCPIP port to take requests and response to SW programs in Control PC, Data Acquisition PC and any other allowed hosts.

THE EPICS UPGRADE

The AWA control and data acquisition system grows with the growing of AWA facility. It was a very centralized system with mostly just some simple HW controlled by tow PXI crate. There was no need for distributed control system like EPICS at the inception of AWA control and data acquisition system. As the result of the growing of AWA facility, there are more and more HW added to the system and it is transforming into more or less a distributed system. It makes sense to upgrade AWA control and data acquisition system to EPICS compatible so that future expansion of AWA facility can share resource between other facility like APS and other facilities.

Phased Upgrade Plan

There is almost one new experiment every 3 weeks at the AWA facility so we can't afford much down time for the upgrade. Also, the AWA is a small facility, so we can't afford to rebuild the control and DAQ system with new HW from scratch. It will not only require funding for purchasing HW, but also down time to install and commission them.

Based on the above, it has been decided that the upgrade will be done in a phased way.

- For phase 1 of the upgrade: we will provide EPICS support on top of existing AWA control system. The goal is to allow both EPICS based control system and the existing control system to function simultaneously so that we can minimize the impact to the operation of AWA facility while operators can get themselves familiarized with the EPICS based control system.
- For phase 2 of the upgrade: phase out the old AWA, non-EPICS control system and transfer the AWA control and Data acquisition system into EPICS only control and DAQ system.

As we won't replace the control hardware during Phase 1 of the upgrade. The EPICS IOCs will be either build inside the existing host computers or in separate host PCs to interact with existing system. The existing control system did provide TCP/IP interface for remote operation, but only limited functions are exposed. It is possible that we modify the existing system to expose all controls to EPICS IOCs, but since we are modifying the program anyways, it is flexible and preferable that if the control hardware involved are strongly tied to a host PC, like those PXI modules, we modify the program in the existing system to integrate an IOC into it. Otherwise, like those stepper controllers/drivers with serial interface or ethernet interface, we will build their associated IOCs in separate hosts.

Status of the Upgrade

Currently phase I is going smoothly. We have integrated and tested EPICS IOCs in AWAHWI and AWASMC running in the Control PC. With the IOCs integrated in those two programs, all the hardware controlled by those two programs (about 70% of the facility) are now exposed to EPICS clients. We also integrated an IOC into AWALLRFCtrl which enables users to control the LLRF setting from their python script using simple EPICS interface. We have integrated EPICS IOCs into Bira power supply control programs running inside the controller modules which exposed the Bira power supplies EPICS. Up to this point, all the beamline magnets, air actuators and most motorized actuators can be controlled from the EPICS side.

We will continue the phase I by upgrading the DA programs and make the EPICS compatible. After that, we will set up the following before we move on to phase 2.

- an EPICS operator station for control.
- an EPICS operator station for data acquisition
- an EPICS archive server
- an EPICS alarm server

SUMMARY

The AWA control and data acquisition system needs to be upgraded in order to keep up with the growth of the facility. With the helps from APS, the upgrade has been carefully planned and is going smoothly.

REFERENCES

[1] Experimental Physics and Industrial Control System, epics-controls.org