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Custom Open Source Solutions for DIII-D Data Acquisition and Control Systems

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Computer based control and data acquisition systems have long played a critical role in fusion research in the development and operation of experiments such as the DIII-D tokamak in San Diego. These systems require great flexibility in being able to control and tie together the many diverse subsystems that make up a tokamak, including power, cryogenic, vacuum, electrical, water, heating and computers. For well over a decade the DIII-D control and data acquisition systems have been running on Linux-based commodity computing hardware. This has provided DIII-D with a continual path of improvement to computing performance and capability while maintaining the usefulness and productivity of numerous custom developed software applications written over the years. The flexibility provided by these Linux based systems has allowed DIII-D to continue to utilize and support legacy CAMAC hardware in addition to incorporating newer PLC and data acquisition hardware. A number of in-house developed tools and applications have made these systems highly customizable and easily expandable in being able to meet the specific and growing needs of the DIII-D research program. Among the latest improvements to these systems have been upgrades to user interfaces, development of new control capabilities and increases to data acquisition capabilities. This paper will describe in detail the present state of the DIII-D computer based control and data acquisition systems and recent improvements that have been made.

1. Introduction

Linux based commodity computing systems have entered the mainstream of both industry and research providing reliable low cost solutions for developing and deploying specialized software applications as well as entire homegrown systems. Fusion research, in particular DIII-D with its highly specialized computing needs has benefited greatly from the growth and wide acceptance of Linux open source based software. A high percentage of the Information Technology infrastructure set up to operate and support the DIII-D tokamak is based on commonly available computing hardware running some variant of the Linux Operating System. This includes a great majority of computers used for Data Acquisition, Control, System Monitoring, Data Storage and Data Analysis. All this is made possible by the numerous open source development tools available for Linux ranging from compilers, databases, source code control tools, graphical user interface packages and complete Integrated Development Environments (IDEs). Linux based computers have provided all the tools and flexibility for developing and maintaining the highly specialized and complex computer control and data acquisition systems incorporated for the DIII-D tokamak.

2. DIII-D Data Acquisition

The DIII-D experiment typically produces over 14 GBytes of raw data from over 3000 diagnostic signals during each pulse. The Linux based data acquisition systems are comprised of a mixture of legacy CAMAC and newer PCI and cPCI digitizer hardware connected to a collection of Intel rack mounted computing nodes. Much of the software used to operate digitizers and to collect, process and archive data have been home grown. This includes a fully functional Linux CAMAC serial highway driver used to control up to two highways from a single computer. The custom GA-developed CAMAC driver supports basic CAMAC read/write commands in both Direct Memory Access (DMA) and non-DMA modes, works with enhanced and normal crate controllers and has been tested with a wide variety of CAMAC clocks and digitizers, including LeCroy, TRAQ, Joerger, Jorway, Aurora and Aeon models. While the CAMAC hardware handles roughly half of the number of signal channels collected, the size of this data only represents a little over 1% of the total volume of data collected by the DIII-D Linux systems.

The rest of the data that is acquired at DIII-D comes from the PCI and cPCI digitizers from D-TACQ Corporation [1]. The cPCI digitizers vary in number of channels ranging from 16 to 96, acquisition frequencies up to 50 MHz, and data sizes of up to 1 Gigabyte per channel. Software for operating and collecting data from these digitizers consists of both vendor-provided and in-house developed codes. Much of the recent volume increases in DIII-D data collection has been directly attributable to the migration from CAMAC based hardware to higher performing cPCI hardware. These digitizers have grown in popularity at DIII-D and are used in a wide variety of diagnostic systems including those for magnetics, Thomson, plasma control and neutral beams. The reason for this growth can be attributable to a number of factors. In addition to their high performance capabilities, the cPCI digitizers have demonstrated high reliability, are easily integrated into the DIII-D computing environment, and have been highly customizable to suit the many specific needs of the DIII-D diagnostic systems. Examples of this customizability include a real-time data acquisition

capability used in plasma control, on board customized signal processing such as is used for the motional Stark effect (MSE) diagnostic, programmable burst mode sampling used by the reciprocating probes diagnostic, and specialized trigger responses tied to laser pulse events required for the Thomson system.

Configuration of data acquisition parameters including settings for clocks, triggers and digitizers is accomplished using custom homegrown databases and software. The DIII-D custom made acquisition configuration system makes it easy to view and update all data acquisition parameters from one experiment to the next and easily add new and remove old and unnecessary data acquisition hardware. A total of fifteen Linux based data acquisition computers are available for the wide variety of DIII-D diagnostics which depending on the needs of a given experiment can be easily enabled or disabled during DIII-D pulses. Custom tailored user interfaces provide controlled access to various kinds of users from computer support staff to physicists for updating different acquisition parameters. The custom developed DIII-D acquisition system has been designed to maximize software reusability allowing systems to easily be cloned either whole or in part and used in creating new and complete data acquisition diagnostics containing everything needed to configure, acquire and archive data.

3. Tokamak Control and NBI Systems

The DIII-D Tokamak Control and Neutral Beam Injection (NBI) systems rely on Linux based computers to handle all the required monitoring, configuration, control, data acquisition and archiving for these systems. Both systems utilize some mix of CAMAC, cPCI and PLC based hardware which are all interfaced using custom in-house developed software. Efforts to reduce reliance on aging legacy CAMAC have been ongoing, but there remains a need to maintain support for a number of analog and digital Input/Output (I/O) modules, timing modules such as the Jorway 221 and a few interrupt modules that are still used for DIII-D Timing and Power Systems. The data acquisition hardware for the NBI systems that at one time accounted for the largest percentage of the CAMAC used on these systems has now been fully replaced by cPCI digitizers. Sensoray [2] single point I/O modules are used for thermocouple temperature monitoring and digital I/O for audio amplifiers, pressure and gas valves. These have provided a nice low cost per channel I/O solution for interfacing to the Linux systems over Ethernet. Custom software drivers have been developed to provide access to network driven GEFANUC [3] and Siemens [4] PLCs to control and monitor DIII-D GAS, Cryogenic and Vacuum systems.

A number of in-house tools and applications have been developed to manage the configuration of these systems and perform all control and monitoring tasks from the Linux computers. These include a DIII-D control database library containing routines for storing and retrieving data associated with DIII-D plant systems into a shared memory region for fast and easy access to device drivers, user interfaces and all other applications running on these computers. A graphical user interface called the Configurator (Fig. 1) provides users with a means of viewing and modifying scanning and control parameters for Analog and Digital Inputs and Outputs, and Miscellaneous Variables which can be used to store and share information not necessarily tied to a specific piece of hardware including calculated results. In addition, the Configurator application allows users to easily edit, create and manage control procedures and user interfaces for the Tokamak Control and NBI systems.

4. Qt Graphics as a User Interface Solution for Linux

While Linux may not be as widely known for its desktop and interface features as it is for its powerful server capabilities it nonetheless provides a more than adequate and in some ways superior solution for deploying and sharing user interfaces amongst numerous computing clients via X11. Using tools such as Qt, a full featured open source IDE [5], users can quickly and easily develop and deploy user interfaces which can be remotely accessed from any system capable of running X11 clients including Linux, Mac and Windows based ones. DIII-D relies on a great number of user interfaces developed specifically to be accessible from X11 clients. These include interfaces used for tokamak control, neutral beam injection, plasma control, data acquisition, real-time data display, and data analysis. Interfaces can be hosted on one or more server computers and run by multiple users without the need for software licenses from various clients located both within and outside the DIII-D facility.

The Open Source Qt Package is freely available and includes complete sources for building the Software Development Kit and graphical user interface builder and IDE on all the major OS platforms. An abundance of documentation, numerous add on packages including a powerful plotting library and ease of customization have made it possible to develop Industry Supervisory Control and Data Acquisition (SCADA) like tools for use in running the DIII-D tokamak. Specific customizations made for DIII-D include a number of customized smart widgets created for the Qt IDE that provide quick and easy linking of user interface elements to control point information associated with hardware monitoring devices and actuators. Examples of this include smart color LED widgets, numeric displays, image widgets and data entry fields. The DIII-D customized Qt IDE has provided an easy to use and well organized platform which has been used to develop applications including the tokamak and NBI control consoles (Fig. 2), real-time scope displays, a Residual GAS Analyzer program and more.

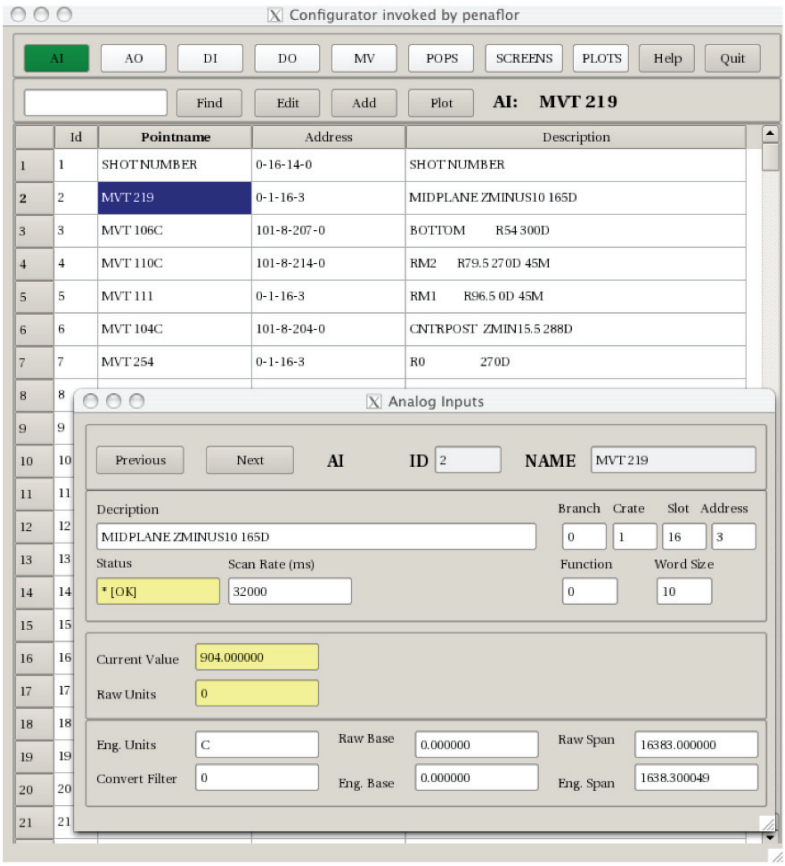

Fig.1 Configurator application.

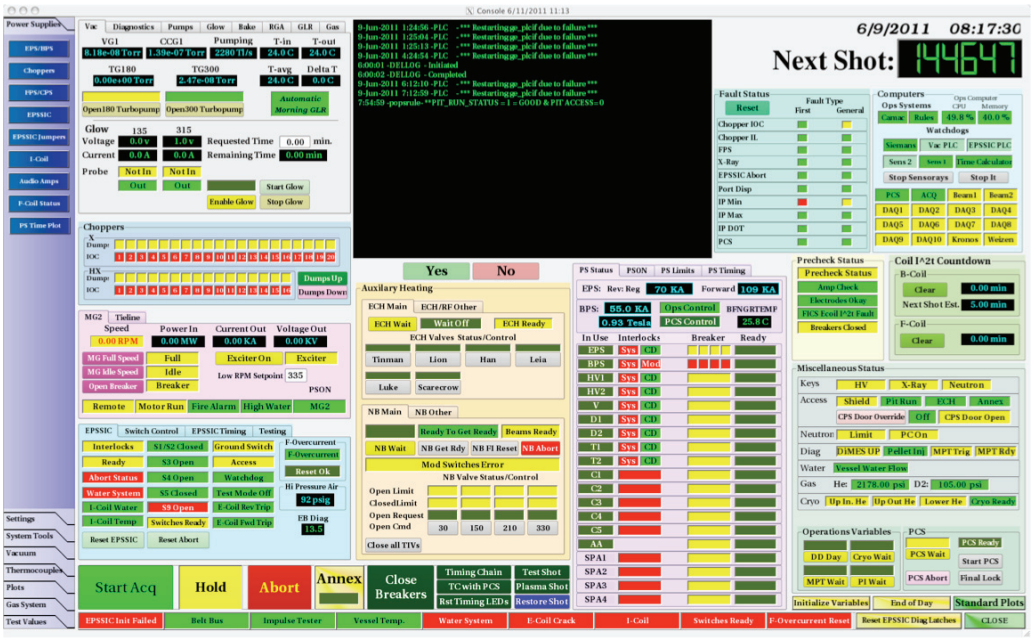

Fig.2 Tokamak Control Computer Console.

5. Overall Experiences and Lessons Learned

The Linux based customized software solutions developed at DIII-D for a number of the data acquisition and control systems have not been without their fair share of problems and challenges to overcome. One persisting problem has been minimal support for device drivers for newer PLC and I/O hardware which have limited the types of hardware which can be used by these systems. This problem has been addressed to some degree by contacting vendors for assistance in development of custom drivers to run under Linux, but requires more time and effort in having to develop and maintain driver software in-house. Another problem has been reliance in the past on commercial applications developed for Linux that have either stopped being supported or have skyrocketing maintenance costs. Examples of this include the discontinued Borland Kylix application which was used to develop the initial user interfaces used by the Linux data acquisition and control computers but have since been replaced using Open Source Qt, and the IDL product used in a number of Data Analysis tools and require expensive licenses in order to use. Despite these particular disadvantages, the Linux based solution overall has been very cost effective and productive to DIII-D.

6. Summary

As the needs of the Fusion Research Program at DIII-D continue to grow and evolve, custom open source software solutions will maintain an important role in helping to meet those needs. With the abundance of powerful, well proven and highly customizable open source tools at hand for use on commonly available computing hardware, the fusion computing group has been able to develop and maintain a wide variety of applications necessary for operating and collecting data from the DIII-D tokamak. From low level device drivers for instrumentation and data acquisition hardware, to real-time plotting applications and full fledged Industry SCADA like systems, custom open source software developed at DIII-D have been able to address a variety of highly specific requirements of the fusion control and acquisition systems.

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References

[1] D-TACQ Corporation www.d-tacq.com James Watt Building Scottish Enterprise Technology Park East Kilbride G75 0QD SCOTLAND UK
[2] http://www.sensoray.com
[3] http://www.ge-ip.com
[4] http://www.siemens.com
[5] http://www.qt.nokia.com