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Application of ITER CODAC Core System for NSTX SPA-2 Project*

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***Abstract*-- The National Spherical Torus Experiment (NSTX) was upgraded in 2011 with a second switching power amplifier (SPA2) to power NSTX's resistive wall mode (RWM) coils. Integration of the power supply's local controls with the Central Instrumentation and Control System (CI&C) was accomplished, in part, through PLC-to-EPICS software that was included in the ITER project's Control, Data Access, and Communication (CODAC) Core System. The Core System is a software suite for ITER plant system manufacturers to use as a template for development of their interface with CODAC. NSTX decided to use this software for the SPA2 project for a number of reasons, principally: 1) it was cost-effective for NSTX, 2) it provided an opportunity to collaborate with ITER and evaluate their Plant System Interface methodologies, documentation, and information technology and control system processes; on an operational machine. This paper will present an overview of the SPA2 CI&C interface and describe our experience using the ITER Core System software and applicable plant system integration processes.**

I. Introduction

The NSTX is a world class spherical torus research machine which is addressing fundamental issues in magnetic fusion energy science. NSTX has been operating at the Princeton Plasma Physics Laboratory since 1999. The Central Instrumentation and Control system [1] (fig. 1) uses the Experimental Physics and Industrial Control System (EPICS). The SPA2 upgrade project was completed in 2011 and will provide additional capability by allowing individual control of NSTX's six RWM coils. This was a multi-discipline engineering effort that required integration with many facets of the CI&C including real-time plasma and power supply control systems, EPICS-based controls, the MDSplus data repository, and NSTX timing and synchronization systems.

During the design of the CI&C interface for the SPA2 controls, engineers realized that the emerging control systems standards being developed by the CODAC section at ITER could be used for the SPA2 project. This was principally a result of the fact that both NSTX and ITER are using EPICS and that the implementation could benefit both NSTX and ITER. This paper will describe our experience applying elements of the CODAC core software [3] for the NSTX SPA2 project.

II. ITER's CODAC Core System

Per ref. [3] "CODAC Core System is the development and interface kit for plant systems I&C based on the widely used open source software EPICS (Experimental Physics and Industrial Control System). CODAC Core System runs on Mini-CODAC, Plant System Host and Fast Controllers and provides an interface to Slow Controllers."

ITER's CODAC Core System consists of a centrally managed and deployed Linux operating system and a suite of application software packages. These applications were already under development within the EPICS collaboration, so NSTX had some familiarity with them, but had not actually used them for NSTX operations. EPICS applications included a database editor, operator display editor, alarm handler, and trending and archiving tools.

EPICS databases contain records, each with dozens of attributes suited to control systems. The records are selected, configured, and linked together using an EPICS database editor to define how the control system behaves. A display editor/manager contains an extensible palette of control and monitoring widgets to create operator displays.

A. ITER Slow Controller

ITER has not only defined standards for software but also for hardware [7]. ITER has agreements with major hardware and software vendors for multi-decade and product availability and support contracts. ITER has selected a family of Programmable Logic Controllers (PLC) from Siemens [4], the S7 series. There are varying levels of cost and performance associated within the S7 family. The medium range line is the S7-300. The high end industrial PLC is a Siemens S7-400. The Siemens Step 7 software, which runs on Microsoft Windows, is required to configure and program the PLC. CODAC provides an EPICS driver used to allow communication between the PLC and the EPICS Input-Output Controller (IOC) which is a standard EPICS component and but one part of the ITER Plant System Host. CODAC provides an extensive toolset to configure and integrate a PLC-based slow controller into the EPICS environment, including a sample PLC configuration

B. CODAC Training

In October, 2010 ITER held a CODAC training course for controls engineers and potential collaborators at the US ITER office located at the Oak Ridge National Laboratory; a NSTX engineer participated. The agenda included an

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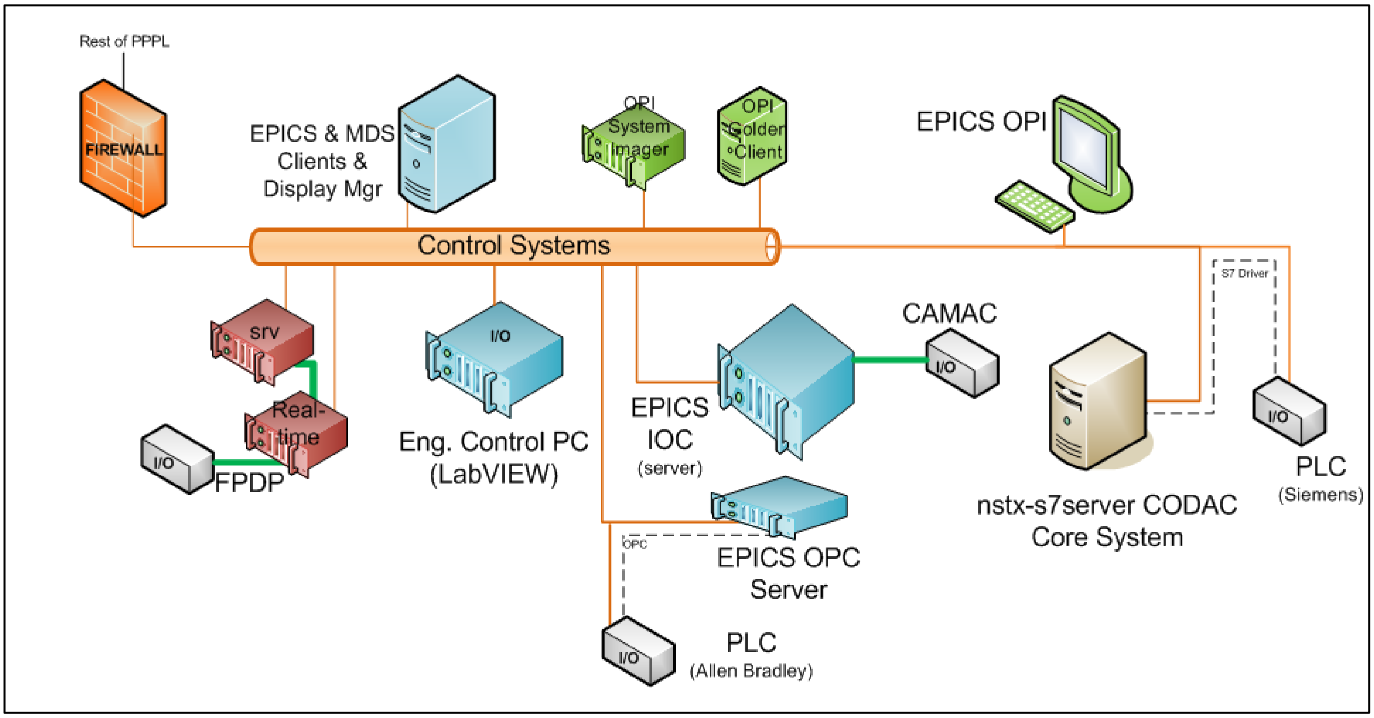

Figure 1: Integration into Existing NSTX Control Systems

introduction to ITER and the CODAC Core system, specifically the Plant Control Design Handbook (PCDH) [5]. Representatives from CODAC made presentations encompassing many important aspects of the ITER control system, including the life-cycle of the project and software. The 'I&C Integrated Architecture' was presented and each component was covered; its purpose, major characteristics, and interfaces. The CODAC website was introduced; this provides access to an extensive set of documents to assist in the definition and management of the control (sub)systems. The to-date achievements and future plans were impressive. After the training, PPPL submitted a request to become an official ITER/CODAC registered user; this has been approved.

C. CODAC and the SPA2 Project

The insight gained through the training experience confirmed that a (informal) collaboration with ITER would be beneficial to both parties: 1) NSTX has used EPICS for over a decade [1], 2) The SPA2 project is using a Siemens S7 series PLC, 3) CODAC technologies and methods could (in part) be applied on an operating fusion device. Our initial experience, coupled with the possibility of more in-depth endeavors in the future will help prepare ITER for its own operations as well as enhancing the support of subcontractors and collaborators.

III. NSTX Experience with CODAC Core

A. Software Installation

There were simple and clear documents to guide the core release installation. This attribute is critical since these installations will not only be at the ITER facility in Cadarache, France, but all over the world as collaborators and sub-contractors develop and test their ITER subsystems. The CODAC Core includes an EPICS IOC running on Linux (part of the Plant System Host). Typical EPICS configuration of the IOC was required. The CODAC Core System included a development methodology for defining the basic PLC/EPICS interface [6], but there was no time to learn and exploit this attractive feature so it was done 'by hand'. The CODAC core package includes many other software utilities; but the NSTX SPA2 project only used a portion due to the aforementioned constraints.

The PLC that was selected for the SPA2 project, the SIL-3 rated S7-315, was compatible with the models that ITER CODAC has standardized on [7]. The PLC system included input/output modules and a networking switch to communicate using Ethernet. On the software side, the CODAC core release provided everything that was required to interface the PLC with the EPICS-based NSTX CI&C.

To establish communications between the EPICS IOC and the PLC, both ends need to be properly configured. The configuration on the EPICS side was fairly well documented [8,9], though the documentation was not directly provided by ITER. The configuration of the PLC for communicating with the IOC using the Step 7 software (for IOC communication) was the most time consuming part of this project. There was no clear documentation for this. However, once a method was discovered the system was robust and allowed for bi-directional communication. Note that the EPICS IOC only had access to values in the PLC if the PLC was configured to allow it.

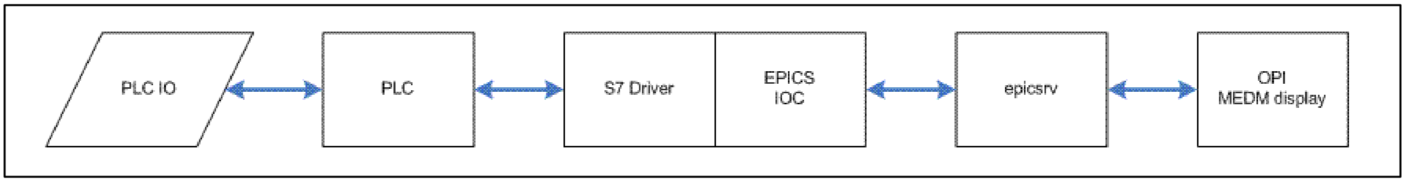

Figure 2: Data Flow in SPA2 Control System

B. Integration into NSTX CI&C

Fig. 2 shows the data flow between the SPA2 equipment, PLC, and NSTX EPICS system. Due to the project's schedule and resource limitations NSTX was not able to delve further into the CODAC core software so NSTX feedback to ITER was less than originally envisioned. Only a few parts of CODAC were used, but, these integrated into NSTX's older EPICS infrastructure quite well.

Since NSTX already had a mature EPICS system which used other (older) EPICS tools, such as the Motif Editor and Display manager (MEDM) [10], the SPA2 project became a hybrid of ITER and NSTX software environments. Due to EPICS's structured and stable communications protocol (Channel Access) [11] the new CODAC-based IOC was able to be seamlessly integrated into the CI&C system.

C. Performance of Production System

NSTX has tested the system and evaluated it under various test conditions. This system has passed the Pre-Operational Test Procedure (PTP) and is ready to be used in the upcoming NSTX 2011 run that is scheduled to be started in July 2011. The control commands have traveled from the MEDM page to the IOC to the PLC and its I/O and have actuated the safety disconnects switches (SDS). Limit switches that indicate the SDS position were successfully indicated on the MEDM display.

IV. Future Plans

There was a lot of software included with CODAC Core System that the NSTX CODAC group could not utilize because of the aforementioned constraints. The purchase of a dedicated PLC for the CI&C staff would allow the support of more data/record types, a more thorough understanding of how the PLC software interacts with the IOC's driver, and the ability to write improved documentation on the Windows Siemens Step 7 software (to configure the PLC for communicating with the IOC). Another reason for NSTX to enhance in-house expertise is to explore replacement of older Computer Automated Measurement and Control (CAMAC) hardware which was used for the original SPA as well as many other NSTX systems. This (PLC hardware) would foster reduced maintenance and more reliable operations during the NSTX experimental run.

Future plans also include installing and testing the next version of CODAC Core System which at the time of writing is version 2.0. Version 2 of the CODAC Core was released in 2011. This uses a more modern and extensible EPICS tool chain based on the Control System Studio (CSS) [12]. CI&C was already considering replacing the older established EPICS applications with the CSS (the ITER-supported variants).

V. Conclusion

After building the system with CODAC's guidance and completing initial tests, we feel that the system is ready to be included in a production run. As of this writing the system has been in pre-operational mode for several months and performing well; the software has never crashed. If this system performs successfully during operations it will establish a real-world test of the CODAC Core System.

This project induced PPPL to become a registered user within the ITER community, providing recognition of PPPL's capabilities and enhances prospects for future collaboration. By using ITER-like hardware and software, the ITER-led long-term support and availability agreements will enhance NSTX's position to have long-term product support.

Acknowledgment

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