# A DISTRIBUTED AND COLLABORATIVE PLC LAB FOR THE SPALLATION NEUTRON SOURCE*

J. Y. Tang, J. D. Smith, Brookhaven National Laboratory, Upton, NY, USA
W. R. DeVan, R. E. Battle, Oak Ridge National Laboratory, Oak Ridge, TN, USA
S. A. Lewis, C. A. Lionberger, Lawrence Berkeley National Laboratory, Berkeley, CA, USA
D. P. Gurd, Los Alamos National Laboratory, Los Alamos, NM, USA

*Abstract*

The control system for the Spallation Neutron Source (SNS) will be developed collaboratively at five different national laboratories. It is expected that many PLCs will be used. Several of the collaborating labs have experience with PLC systems, but not all use the same hardware and some of the hardware is obsolete. New PLC technology is now available. A collaborative and distributed PLC development lab has been established to help select the most suitable industrial systems and devices for the SNS project. In this paper, we present the configurations, features, performance, reliability and a cost comparison of the prototype systems we have reviewed. The selected PLC development projects cover the following areas: using soft PLCs; linking PLCs with TCP/IP-based protocols or the ControlNet™ network; integrating input/output modules via the DeviceNet™ network; using PLC I/O modules such as Flex-I/O™ and G3™ without ladder-logic to exploit their form-factor and electrical properties; and comparing the low-cost PLC systems against the most popular brands. The integration of the PLC prototypes with EPICS will be discussed.

## 1 INTRODUCTION

The Spallation Neutron Source (SNS) is an accelerator-based 1 – 2 MW pulsed neutron source to be built in Oak Ridge, Tennessee. A fully integrated control system for the SNS facility will be developed collaboratively at five different national laboratories and the integration of the control system will be based upon the widely used EPICS control system toolkit [1]. It is expected that many PLCs will be used in the system. Several of the collaborating labs have experience with PLC systems, but not all use the same hardware. Some of the hardware models have been in the market for more than fifteen years while new PLC technology is now available. A collaborative and distributed PLC development lab has been established to help select the most suitable industrial systems and devices for the SNS project.

In this paper, we first describe the configurations of the prototype systems we have reviewed. Then the following topics will be covered: 1) the two methods that we have chosen to link PLCs with TCP/IP based protocols; 2) the comparison of Allen-Bradley's PLC-5, SLC500, and ControlLogix PLCs on costs, performance, functionality, and reliability; 3) the experience of using Group3™ technology; 4) the experience of using Flex-I/O™ technology; 5) integrating I/O modules via DeviceNet™. Finally, the recommendations on selecting PLCs for the SNS project will be given.

## 2 THE SNS PLC LAB

### 2.1 The configuration of the SNS PLC lab

To help select most suitable industrial systems and devices for the SNS project, a collaborative and distributed PLC development lab has been established as shown in Figure 1.

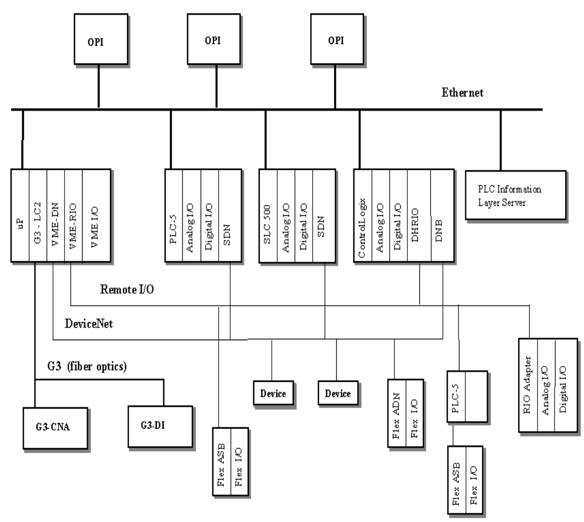


Figure 1: The SNS PLC Lab

The SNS PLC lab is configured collaboratively at Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), Las Alamos National Laboratory (LANL), and Oak Ridge National Laboratory (ORNL).

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Each collaborating lab has been working on one or two areas of the selected PLC development projects:

- At ANL, it has shown the success of using EPICS as a soft PLC that communicates with Allen-Bradley I/O modules via a VME Remote I/O scanner. The I/O control logic is implemented in EPICS databases. For details, see [2].
- At BNL, the prototype systems of linking PLCs with TCP/IP based protocols and integrating I/O modules via DeviceNet are under development.
- At LBNL, both Group3 and Flex-I/O technologies have been used for their prototype systems.
- At LANL, a PLC EPICS record is under development to streamline PLC to EPICS (This topic will not be covered).
- At ORNL, DeviceNet™ is being used for an optional link between VME EPICS controller and PLCs.

## *2.1 Linking PLCs with TCP/IP based protocols*

Ethernet technology has advanced rapidly in recent years. The Control and Information (CIP) protocol for real-time on Ethernet is being developed by The ControlNet™ International, Ltd. Two methods of linking PLCs with the SNS control system via Ethernet have been investigated:

- *Via a PLC Information Server*
  A PLC Information Server is configured with a portable Channel Access server and the RSLinx™ (PLC Ethernet interface driver) running on a NT™ station This method centralizes the communication between PLCs and the upper layer of the control system. It avoids redundant PLC I/O requests to PLCs. A PLC processor, therefore, is able to dedicate its time for more time critical low-level tasks.
- *Directly communicate with the Ethernet interfaced PLCs*
  Another approach is to implement an EPICS PLC Ethernet driver that directly communicates with PLCs. However, the Ethernet protocol for Allen-Bradley programmable controllers is Allen-Bradley proprietary information. A Confidentiality Agreement for the protocol between Rockwell Automation and Brookhaven National Laboratory has been signed. An EPICS driver for Allen-Bradley Ethernet PLC is under development for evaluation purposes only.

## *2.2 PLC-5, SLC500, or ControlLogix*

Allen-Bradley PLC-5 and SLC500 are widely used industrial control processors. PLC-5 has been in the market more than fifteen years and SLC500 for more than ten years. Both processors are currently used for other projects at all five SNS collaborating labs. There are many engineers at the SNS collaborating labs who have many years of experience with PLC-5 and SLC500. On the other hand, a new PLC model, ControlLogix, has been in the market only for about two years. ControlLogix is about 8~10 times faster and 30% cheaper than PLC-5. The comparison of PLC-5, SLC500, and ControlLogix on costs, performances, functionality, and reliability is summarized in Table 1.

Table 1: PLC-5, SLC500, or ControlLogix

| | **PLC-5** | **SLC500** | **ControlLogix** |
|---|---|---|---|
| **Costs** | 1 | 35% | 65% |
| **Years in Market** | 15 | 10 | 2 |
| **Reliability** | Similar MTF records | | Too new to be measured |
| **Functionality** (Special I/O modules availability) | Most | 2nd | Least (it has the capability to talk with PLC-5 I/O modules via adapter) |
| **Performance** | Similar performances | | 8 ~ 10 times faster than PLC-5 |
| **In-house expertise availability** | About 40 engineers at BNL | | Only one recently has been trained |

## *2.3 Experience using Group3™ Technology*

The Group3™ interface combines fiber-optic cable, a VMEbus loop controller, and up to 32 slave units. LBNL intends the fiber to provide up to 65kV standoff and significant protection against sparking and ground loops in the front-end. The slave units are of two varieties: a mini-chassis holding up to three boards of mixed type; or a combination unit (CNA) with analog/digital in/out.

LBNL has written EPICS driver support for the Group3 VME loop controller, as well as specific EPICS device support for a variety of slave units (CNA, analog, digital, stepper motor, DC motor, serial). Additionally, the remote diagnostic/ configuration capability (running concurrently with normal I/O over the fiber loop) has been extended to work via Channel Access, and a client application is provided to emulate the hand-held unit that connects directly to the diagnostic port. A utility has been written to save, restore, and compare the contents of configuration RAM for any slave unit.

With the CNA unit used one-to-one with each power supply, we exploit one of the relays to loop the DAC back

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(under program control) into the second ADC channel in place of the external readouts. The motor units are matched one-to-one with the mechanism being controlled, since they include digital inputs for limit switches and analog inputs for “follow pots.”

## *2.4 Experience using Flex-I/O™ Technology*

Flex-I/O™ is an Allen-Bradley interface family usable with any of their PLC units or directly with their VMEbus scanner. LBNL has is using Flex-I/O™ in both configurations for its convenient form-factor (modular, DIN-rail), low cost, and rugged electrical characteristics. For both interlock and vacuum systems in the front-end, we will combine the PLC/5 ladder-logic with Flex-I/O “stacks” situated close to clusters of pumps, valves, and gauges. For extensive temperature and monitoring, we will connect it directly (no ladder-logic).

LBNL has added EPICS device and record support to enable use of the Flex-I/O 1794 units for digital in/out (-IB16 and -OW8) and analog in/out (-IE8, -OE4, -IE4XOE2). Additional support has been added to enable block transfer operations to a PLC/5 configured simultaneously in adapter-mode (seen by VMEbus scanner) and in scanner-mode (controlling Flex-I/O).

## *2.5 Integrating I/O modules via DeviceNet™*

DeviceNet™ is an open network standard. There are more than 150 companies that develop products that are compatible with the DeviceNet network. It is a simple, networking solution that reduces the cost and time to wire and install industrial automation devices, while providing interchangeability of devices from multiple vendors.

Two VME DeviceNet™ interface modules are currently under evaluation at BNL and ORNL. The EPICS DeviceNet™ drivers for these two modules are currently under the development by the joint effort from the two labs. In Table 2, EPICS links, DeviceNet™ features and costs of these two modules are listed.

Table2: IP-DeviceNet vs 5136-DN-VME

| | **IP-DeviceNet** | **5136-DN-VME** |
|---|---|---|
| **EPICS link** | The IP module is configured with VIPC616 VME IP carrier. The EPICS driver is under the development at BNL | An EPICS driver for this VME DeviceNet™ scanner will be developed by ORNL and BNL |
| **DeviceNet features** | I/O Slave Messaging: polling | Master scanner Messaging: Explicit Peer-to-Peer I/O Slave Messaging: Bit Strobe/Polling/Cyclic/COS |
| **Cost** | IP-DeviceNet: $475 IP-Carrier (carry 4 modules) : $1020 | $1590 |

# 3 CONCLUSIONS

It is desirable to standardize on a limited number of PLC manufactures and models to reduce effort to develop EPICS software drivers, to reduce operations effort to support multiple PLC models, to obtain the best pricing by pooling of orders and to concentrate efforts to develop best practices. However, there is always a trade-off when one chooses one model over the other. A collaborative PLC lab will help make such decisions. We recommend the following:

- Consider the availability of in-house expertise when calculating the costs;
- Choose as new technology as possible for easier future upgradability;
- Use open standard networks for interchangeability of devices from multiple vendors.

# REFERENCES


[1] B. DEVAN and etc., “Plans For A Collaboratively Developed Distributed Control System For The Spallation Neutron Source”, PAC99, New York

[2] M. KRAIMER and etc., “EPICS: Allen Bradley Driver and Device Support”, http://www.aps.anl.gov/xfd/SoftDist/swASD/allenBradley



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