Distributed Implementation Plan for a Large, Distributed Accelerator Control System

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Abstract

The proposed Spallation Neutron Source (SNS) is an accelerator-based 1 – 2 MW pulsed neutron source to be built in Oak Ridge, Tennessee. The facility has five major sections "a front end" consisting of a 65 Kev H^- ion source followed by a 2.5 MeV RFQ; a 1 GeV linac; a storage ring; a 1 MW spallation neutron target; and the conventional facilities to support these machines. These components will be designed and implemented by five collaborating institutions: Lawrence Berkeley National Laboratory (front end); Los Alamos National Laboratory (linac); Brookhaven National Laboratory (storage ring); Oak Ridge National Laboratory (neutron source and conventional facilities); and Argonne National Laboratory (instruments). It is proposed to implement a fully integrated control system for all aspects of this complex. The integration will be based upon the widely-used EPICS control system toolkit. This paper introduces the SNS project, discusses the technical and organizational issues of planning a large control system to be developed collaboratively at five different institutions, and describes approaches being taken to address those issues.

1 Introduction

The Spallation Neutron Source (SNS) will be a 1 MW (upgradable to 2 MW) accelerator-based facility that produces pulsed beams of neutrons by bombarding a mercury target with intense beams of 1 GeV protons. It is being designed primarily to meet the needs of the neutron scattering community, with operations expected to begin in 2005. Some reference design parameters are given in Table 1.

The SNS is a truly collaborative project, with the participating laboratories taking lead roles and responsibilities for specific sections of the complete facility. Laboratories were chosen on the basis of their expertise in particular technology areas. The lead laboratory for a given section is responsible for assembling all necessary resources to accomplish not only the design but also the fabrication, testing, installation, and commissioning of its part of the SNS at the Oak Ridge site. Specific roles and responsibilities are as follows:

- ORNL is responsible for overall project management and coordination; for conventional facilities and construction; for maintaining and operating the SNS once completed; and for managing future upgrades.
- LBNL is responsible for the front end systems, including ion source and RFQ.
- LANL is responsible for the linac systems and has coordination responsibility for the controls design.
- BNL is responsible for the accumulator ring and associated transport lines.
- ORNL is responsible for the primary target system.
- ORNL and ANL are jointly responsible for the experimental systems (instruments, beamlines, choppers, etc.).

Table 1- Design Parameters

REFERENCE DESIGN PARAMETER	INITIAL (1.0 MW)	UP-GRADE (2.0MW)
Pulse repetition rate	60 Hz	
Peak ion source H- current	35 mA	70 mA
Linac length	493 m	
Linac duty factor	6.2%	
Linac final beam energy	1.0 GeV	
Accumulator ring circumf.	220.7 m	
Ring orbit rotation time	841 ns	
Pulse length at ring injection	546 ns	
Kicker gap at ring injection	295 ns	
Ring filling fraction	65%	
Number of injected turns	1225	
Ring filling time	1.02 ms	
Protons per pulse on target	1.04 X 10^{14}	2.08 X 10^{14}
Protons per second on target	6.3 X 10^{15}	1.25 X 10^{16}
Time avg. beam current	1.0 mA	2.0 mA
Beam power on target	1.0 MW	2.0 MW

2 Project management

"Memoranda of Agreement" (MOAs) formalize agreements between the SNS Project, represented by ORNL, and each of the participating laboratories. Each MOA covers general provisions for laboratory management, cost and overhead, resource allocations, communication, change procedures, and reporting requirements. Requirements as to the technical scope of work are detailed in addenda specifying how R&D, design, fabrication, installation, and commissioning activities will be carried out. Control system tasks, both on a local and global level, will be covered under these MOAs.

The organizational structure of SNS includes a controls group leader reporting directly to the project director, at the same level organizationally as the leaders of the other major technical areas such as the linac, ring and conventional facilities. This structure recognizes the importance of the integrated control system to the overall success of the project. It also places the controls group leader in position to mediate differences between laboratories.

Distributed control system tasks have been placed within the project′s Work Breakdown Structure (WBS) under the technical area served. For example, the linac control system falls under the the linac s section of the WBS. However, global control functions have been assigned a WBS section of their own. To facilitate management and integration of the various control subsystems, the control system group leader will be given authority over the budgets for control system tasks regardless of where they fall in the WBS.

3 Communication within the collaboration

The heart of communication throughout the collaboration is the monthly collaboration meeting. These meetings are held at each collaborating laboratory in rotation so that the complete team for each laboratory can attend every few months. Meeting agenda include current and upcoming activities, action items, project-wide decisions and concurrences, and the status of technical work. The control systems working group (see section 4 below) frequently meets in conjunction with these meetings.

A network server with a file transfer protocol (FTP) front end was established at the project office at ORNL to capture electronic data and documents. Personnel at ORNL can log on directly to the server, and team members at other laboratories can access it via FTP. Direct remote log in will be available shortly.

An Oracle data base (linked to the SNS Project Information World Wide Web Page), has been established to gather, store, process, and make available project data. Web page access is password-protected, and the data base is organized around the project WBS. It is presently being used to manage accelerator and target physics parameters and to process project cost estimate information. Engineering parameters, the project schedule, and a master equipment data base are near-term expected uses. Eventually the system will be used for procurement status reports, work package and earned-value tracking, and other project management uses.

The formation of a collaboration to implement SNS is one of the project s greatest strengths; it gives the project access to a wealth of expertise and experience. However, it also presents formidable challenges to the implementation of a facility-wide integrated control system. Traditionally, the five laboratories have differing approaches. Geographical separation between laboratories adds another complication. These challenges have been recognized by project management and efforts are being made to mitigate them. Specific actions being taken to ensure that SNS will have a truly integrated control system are discussed in the following sections.

4 SNS control systems working group

The importance of coordinating the controls effort for such a widely distributed project was recognized very early in the project. A Control Systems Working Group was appointed with members from each of the collaborating institutions. This group interacts using telephone conference calls; and, when appropriate, meets at the same time as the SNS collaboration meetings described above.

The working group is recognized by SNS management at the same level as the project leaders for each of the major sections: front end, linac, ring, neutron source, instruments and conventional facilities. The working group has two principle areas of responsibility and activity:

- design and implementation of common or ″global″ systems such as network infrastructure, system software, common applications (e.g. archiving, save and restore, operator interface), timing and synchronization subsystem, beam permit and fast protect systems, control room design, etc; and
- establishing standards to be applied to the distributed control systems which are the responsibility of the various sections of the project. These will include distributed processors, preferred I/O modules, fieldbuses, interface standards, PLCs, isolation standards and a uniform device and signal naming standard.

The working group will not itself design or implement ″global″ systems, but instead will specify requirements and criteria, allocate the work among the collaborators, and oversee its progress. The lead laboratories themselves have responsibility for implementing the controls required for their assigned sections of the facility. This includes I/O modules and crates, local database development, special applications and automation, etc.

5 Initial standardization decisions

Integration

One of the first decisions made by the working group was that the SNS control system should be completely integrated. That is, a single infrastructure and set of standards would be applied to all aspects of the facility. This approach was not entirely obvious. It was certainly conceivable to have each collaborating team develop a system of their own, using approaches in use at their home institutions, and then to superimpose an integrating superstructure. Moreover, it has not been the usual practice in accelerator laboratories to include either target and experimental instruments or conventional facilities (power systems, plant cooling systems, HVAC, etc) in the accelerator control system infrastructure. Related to this approach was agreement on a flat architecture, that is, an architecture which minimizes hardware layers. The more obvious approach of a distributed system, particularly suited to the SNS situation of distributed development, was also agreed. Finally, it was decided that the popular toolkit approach was appropriate.

EPICS

The inaugural meeting of the contol systems working group determined that all five of the collaborating laboratories had operating EPICS[1] systems, and that three of the working group members had themselves direct experience in the development of EPICS-based systems. The experience base that this represented, the track record of EPICS, the recognized need for an open system standard, and the general acceptance of EPICS in the accelerator community quickly lead to a decision to use the EPICS model as the basis for the SNS control system. This decision represents an important first step in the attainment of an integrated control system. Not only did the project reach a quick consensus on underlying infrastructure and toolkit, but that consensus was reached early enough to allow time to prepare standards and examine remaining integration issues.

Interface

A second important decision was the definition of a default interface to the control system at the input to a crate-based system. The transducer or measuring instrument itself belongs to the system it is in, as does the cabling from the instrument to the I/O module front panel. Standards will be established for the signals presented to these modules. Ownership of signal and break-out boxes remains to be established.

This approach is consistent with the way in which the initial SNS cost estimate was developed. The definition above is only the default interface. It is understood that this definition can be modified on a case-by-case basis. Probable exceptions are in the beam instrumentation and low-level RF systems, where sophisticated and custom I/O modules are likely to be developed and packaged in specialized form-factors such as VXI. The default interface is shown in Figure 1.

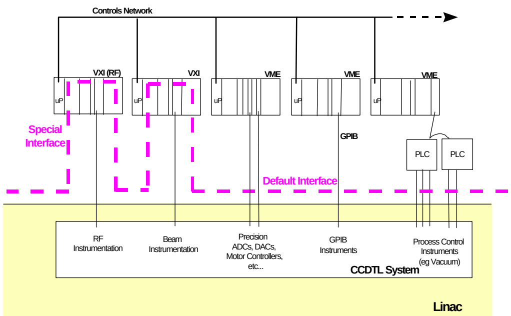

Figure 1-Interface to SNS Control System

Notwithstanding the existence of this default interface, it is the intent of the controls group to develop a series of detailed interface definition documents to delineate between subsystem and global functions, and to assure a seamless interface between parts of the control system executed by different institutions.

Device naming convention

A critical element of the integration strategy is a consistent, hierarchical, plant-wide naming convention. From the operational and control system point of view, the naming convention will provide standard names for devices and signals. However, these names should also be integrated with all aspects of the project models, equipment databases, cable plant databases, etc. The goal is to adopt a naming convention that is unambiguous and clear but at the same time flexible and easy to use. The names and method will represent the official names of devices, will be used in control system databases, and will appear in archives of logged data and with error messages. The naming convention is currently being developed and should be ready for use soon.

6 Technical issues

The most interesting technical issue facing the SNS controls team has to do with timing and synchronization. The entire accelerator chain, including accelerating structures, choppers and bunchers, injection and extraction kickers and data acquisition systems must be synchronized with each other and with a large number of independently-phased neutron choppers. These choppers, a key element in all of the neutron scattering experiments, are large, rapidly rotating (thousands of rpm) flywheels with slots, which are used to select neutrons of a specific energy from the spectrum emitted by that target. Where there is a single chopper, protons can be extracted based upon a signal from that chopper. Where there are several choppers, the question becomes: ″who is the boss?″. The solution to this issue affects both the rf low-level and power systems, as well as the timing and synchronization system. A workshop has been planned to discuss the most appropriate strategy for SNS.

7 Conclusions

A collaboration of five national laboratories is proposing to construct a 1 MW (upgradable to 2 MW) accelerator-based pulsed spallation neutron source (SNS) in Oak Ridge, Tennessee. The control system is being overseen by a working group with members from all participating institutions, and is recognized organizationally as a component equal to each of the accelerators. The control system design will be integrated over the entire facility, and will be based upon the commonly used EPICS toolkit.

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[1] Experimental Physics and Industrial Control System. EPICS is cooperatively developed by many collaborators, primarily at LANL, ANL and TJNAF. It is now in use at over 80 institutions worldwide for accelerators, telescopes, detectors, large industrial plants and a variety of smaller experiments and instruments.