DESIGN OF THE CONTROL AND DATA ACQUISITION SYSTEM OF THE NEUTRON SPIN ECHO SPECTROMETER AT THE SPALLATION NEUTRON SOURCE

H. Kleines, M. Butzek, M. Drochner, P. Kaemmerling, T. Kozielewski, M. Monkenbusch, M. Ohl, F. Suxdorf, M.Wagener, Forschungszentrum Jülich, Jülich, Germany

Abstract

The Jülich Centre for Neutron Science (JCNS) is constructing a new “best-of-its-class” Neutron Spin Echo Spectrometer (NSE) at the Spallation Neutron Source (SNS) in Oak Ridge. Recently, JCNS implemented a NSE at its branch lab at the FRM-II reactor in Garching with a control and data acquisition system based on the so-called “Jülich-Munich Standard”. The “Jülich-Munich Standard” is a set of standards and technologies commonly accepted at the FRM-II which is based on the TACO control system developed by the ESRF. The same approach shall be used for the NSE at the SNS, since many components and structures are common for both instruments. On the other hand local SNS standards have to be supported, leading to additional requirements for the control and data acquisition system.

INTRODUCTION

In order to further strengthen its neutron research, Forschungszentrum Jülich founded the JCNS (Jülich Center of Neutron Science) on its own campus with branch labs at the ILL in Grenoble, at the Spallation Neutron Source (SNS) in Oak Ridge National Lab (ORNL) and at the FRM-II (Forschungsreaktor München II), the new high flux neutron source operated by the Technical University of Munich (TUM) in Garching near Munich. At the SNS, JCNS is constructing a new Neutron Spin Echo Spectrometer (NSE), which will start commissioning in autumn 2008. This SNS-NSE will be “best-of-its-class” with regard to energy resolution and dynamic range. Using superconducting precession coils will allow for a stray field compensated main precession fields with unprecedented field integral up to 1.5 Tm [1].

Recently, JCNS implemented a NSE at its branch lab at the FRM-II. This so-called J-NSE is in its commissioning phase now and its control and data acquisition system is based on the so-called “Jülich-Munich Standard”. The “Jülich-Munich Standard” is a joint effort of ZEL (Central Institute for Electronics of Forschungszentrum Jülich) and TUM to define a common framework for the electronics and software of neutron instruments that is followed by most instruments at the FRM-II [2]. It is based on the TACO control system developed by the ESRF and the extensive use of industrial type front-end equipment, e.g. PLCs, fieldbus systems or remote I/Os. Since there are many components and structures that are common for both instruments, and since ZEL is responsible for the control and data acquisition systems of both instruments, the same technologies shall be used for the SNS-NSE. On the other hand local SNS standards have to be supported, since the SNS-NSE shall fit into the DAQ-infrastructure of the SNS, e.g. regarding data formats, interface to the timing system or the ability to include local sample environments.

OVERVIEW OF THE NSE AT THE SNS

Neutron spin echo spectrometers offer the highest energy resolution of all neutron instruments and are especially well suited for the investigation of polymer dynamics. The spin echo technique is a time of flight method that codes small individual neutron velocity changes into polarisation differences. Polarised neutrons pass two precession coils with identical magnetic field. Between the precession coils they are scattered at the sample and undergo an effective time reversal by a π-flipper. Without velocity change the precession angle of a neutron will be unchanged when exiting the second precession coil. If neutrons experience a velocity change by scattering, the velocity change is coded into a change of the precession angle. Only neutrons of one polarization direction pass an analyzer before a two-dimensional detector [3].

Conceptionally, the NSE instrument can be subdivided into the primary and the secondary spectrometer. The primary spectrometer includes the neutron guide system with removable segments allowing the adjustment of the moderator-detector distance between 18m and 27m. A cascade of 4 choppers separates neutron frames, which come from the pulsed source. For different neutron wave lengths polarizing benders in the neutron guide can be exchanged by a revolver system. The whole neutron guide system is evacuated.

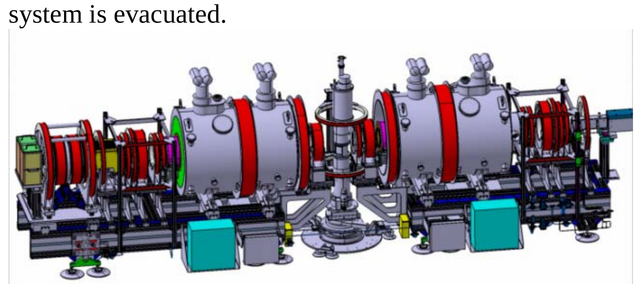

Figure 1: NSE secondary spectrometer; detector is on the left side.

Fig. 1 shows the secondary spectrometer. Main components are the two main precession coils, which have to be superconducting in order to achieve the high magnetic field integral required by the desired resolution. Additionally, 32 auxiliary coils are required, e.g. in order to change the polarization direction or to correct field inhomogeneities. The correction coils are mounted on hexapod systems allowing automatic positioning. The sample stage sits in the middle between the precession coils. Samples can be rotated and lifted. For the positioning of the detector to different scattering angles the whole second spectrometer arm with the detector is turnable around the sample stage centre point. Movement of the whole secondary spectrometer in neutron guide direction allows different moderator-detector distances.

Main control tasks are related to the mechanical movements, the remote control of the power supplies for the coils, the vacuum system, the cooling system for the superconducting coils and the support of a variety of controllers (temperature, pressure, ….) for the sample environment. The detector manufactured by DENEX is a two dimensional multi-wire proportional chamber with delay line readout. Data acquisition is responsible for the readout of the detector and several ^{3}He counting tubes for beam monitoring. Since the SNS is a pulsed source, the detector data and the monitor counters must be time-resolved. Also the choppers and several rampable power supplies have to be synchronized with the SNS pulse.

THE “JÜLICH-MUNICH STANDARD”

The “Jülich-Munich standard” is a framework for the selection of technologies and components at each level of the control system. The definition of this framework was motivated by synergy effects and the reduction of spare parts on the shelf. A guiding principle for the framework was to minimize the development efforts and to acquire as much from the market as possible. A key component of the framework is the consistent use of industrial technologies like PLCs, fieldbus systems or decentral periphery in the front end. Main motivations are:

- low prices induced by mass market,
- inherent robustness
- long term availability and support from manufacturer
- powerful development tools

A control system according to the Jülich-Munich Standard is organized hierarchically into the following levels:

Field level: The field level is the lowest level, at which devices that are not freely programmable reside, like motor controllers, SSI controllers, PID controllers, analogue and digital I/O modules, or measurement equipment. For all industrial type of I/O modules PROFIBUS DP based decentral periphery is recommend. Siemens ET200S is the preferred one. JCNS predominantly use the stepper motor controller 1STEP from Siemens.

Control level: The control level resides on top of the process level. Devices at the control level are freely programmable. They must meet real time requirements and guarantee robust operation in a harsh environment. At the control level Siemens S7 PLCs, mainly from the S7-300 family, are used, because they dominate the European market.

Process communication: Process communication covers the communication of devices at the field and control level with supervisory controllers or computers. For lab equipment GPIB and proprietary RS232/RS485 connections are unavoidable. For industrial automation equipment PROFIBUS DP is the recommended choice. It is the dominating fieldbus in Europe and is naturally supported by S7 PLCs and many other devices. A major reason for its success is the technological and functional scalability based on a common core as well as the programming model, which easily maps to PLC operation.

Experiment Computer: For economical reasons, all experiment computers should be PCs. Linux, being well established in the scientific community, is the only supported operating system. There is no definition of a specific kernel version or distribution. Direct device access should not be implemented on conventional PCs but on CompactPCI systems. CompactPCI allows deploying a variety of existing software in a mechanically more robust platform that fits into 19” racks.

Middleware: Since the framework aims at an inherently distributed system, software support for the transparent distribution of services between systems is required. For this purpose TACO has been selected as the middleware system. TACO is a client-server framework developed for beam line control at the ESRF in Grenoble. In a TACO environment each device or hardware module is controlled by a TACO server. The server offers a set of device-specific functions, which can be accessed by TACO clients via a RPC-based mechanism over a TCP/IP network. To make its functions available to clients, the device server registers itself with the so called manager process. The manager operates as a name server, which is consulted by clients to get the actual location of a server. TACO includes a simple database for sharing of configuration data and operational variables between clients and servers.

Application level: On the client side, two variants of application programs are used: Where flexibility is desired and no GUI is needed, the scripting language Python is used. More static GUI applications are implemented in C++, using the “Qt” class library, with TACO access provided by device specific C++ wrapper classes.

THE NSE CONTROL AND DATA ACQUISITION SYSTEM

Requirements of the SNS

Instrument networks at the SNS have to follow a fixed addressing scheme in a 192.168.xxx.xxx private network [4]. Access from the SNS network is protected by a firewall on a gateway computer. The NSE has to conform to the conventions and interfaces of the proposal and archiving system at the SNS, which require measurement data to be written in the so-called Pre-NeXus format, which finally will be translated into the NeXus format. The timing pulse is decoded from the SNS timing system by the so-called ETC card, a PCI board developed by the

SNS. The data acquisition group at the SNS relies on the data socket protocol from National Instruments for device access. Support of this protocol would ease the integration into the local DAQ infrastructure, e.g. enable use of systems from the sample environment.

Since the control systems of the SNS LINAC, storage ring and target are based on EPICS, support of EPICS client functionality is required to access resources of these control systems, e.g. for reading the moderator temperature.

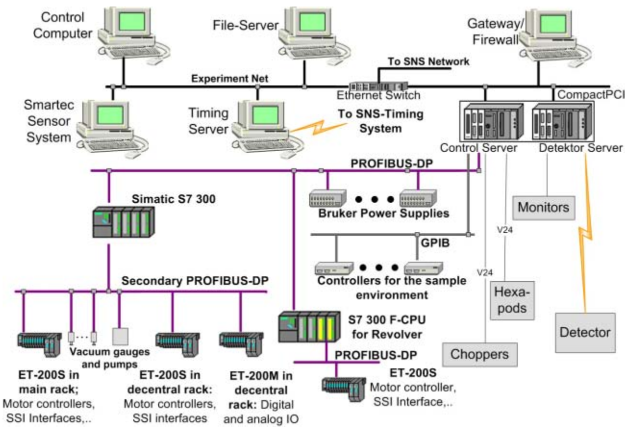

Figure 2: Physical architecture of the NSE control and data acquisition system.

Physical Architecture of the Control System

According to Fig. 2 the control and DAQ system is implemented as a distributed system with a hierarchical architecture. On top of the system resides the so-called control computer with all application software – GUI-based as well as script-based. Additional computer systems are used as file server and gateway to the SNS network. Via the experiment network the control computer accesses the “server computers”, to which all front end systems (detector, monitors, position encoders, motor controllers, ETC card,…) are attached. On the “server computers” TACO servers are running, which access the peripheral devices via dedicated device drivers.

The “slow control” peripherals are indirectly connected to the “server computers” via a PROFIBUS segment with two S7-300 PLCs and all the controllers for the power supplies from Bruker. Most motor controllers and position encoders interfaces reside in ET200 decentral periphery systems scattered over the instrument, which are connected to the PLCs via an additional subordinate PROFIBUS segment.

Software Architecture

As shown in Fig. 3, the implemented software is distributed between three levels of the system hierarchy. All software below the lower dashed line runs on PLCs in the front end. The software modules shown between the dashed lines are running on the server computers. This comprises TACO servers and device drivers for dedicated HW modules, e.g. detector electronics, counter board, PROFIBUS controller, GPIB controller or SNS timing card. Additional TACO servers act as a generic EPCIS client and a generic NI data socket client, in order to get access to SNS control system resources or the existing DAQ infrastructure of the SNS. The TACO middleware is the glue that connects the server computers to the control computer, where the client application programs as well as the TACO manager and database (all above the upper dashed line) are running. Since TACO is location-transparent, the application programs could run on any Linux-based system.

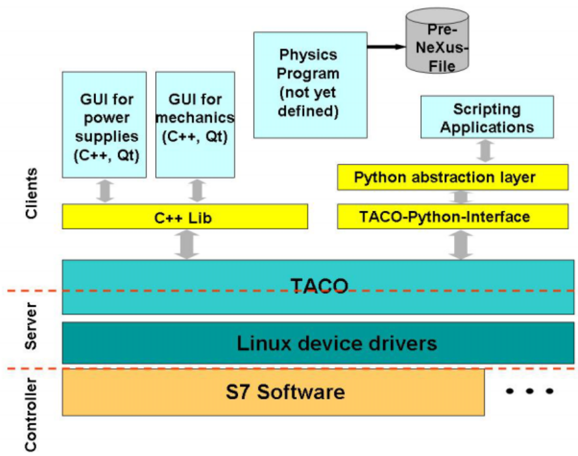

Figure 3: NSE Software structure.

One GUI-based program enables comfortable interactive operation of all power supplies. A further GUI-based program visualizes the mechanical setup of the instrument and allows interactive control of each axis, in order to support service by technical personnel. A thin abstraction-layer implemented in Phython above the generic TACO-Python binding hides many details from the user, e.g. it allows the use of symbolic names and provides the conversion between device units and physical units. This abstraction layer provides a comfortable script access to all spectrometer features. The main physics program will communicate via C-calls with the Phyton-Taco subsystems. It will be a clone of the J-NSE operation program written in C with added features for the TOF-data structure and a few time-dependent current functions

REFERENCES

[1] M. Ohl et al., „High resolution neutron spin-echo spectroscopy facilities at JCNS”, FZ Jülich Annual Report 2005.

[2] H. Kleines et al., “Implementation of the Control and Data Acquisition Systems for Neutron Scattering Experiments at the New “Jülich Center for Neutron Science” According to the “Jülich-Munich Standard”, Proceedings of the ICALEPCS 2005, Geneva, 2005.

[3] D. Richter et al., “High Resolution Time-of-Flight Neutron Spin-Echo Sprectrometer for the SNS”, HGF additional funding proposal, Jülich, 2003.

[4] R. Riedel: “Overview of Data Acquisition at the SNS”, ORNL internal report.