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"

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ABSTRACT

The newly founded JCNS (Jülich centre of Neutron Science) will operate eight neutron scattering experiments at its branch lab at FRM-II (Forschungsreaktor München II) in Garching. Three of these instruments will be designed completely new and five experiments, being operated now at FRJ-2 (Froschungsreaktor Jülich 2), will be transferred from Jülich to Garching after a major innovation, when FRJ-2 is shut down in May 2006. All experiments will get new control and data acquisition systems with electronics and software based on a common framework, the so-called Jülich-Munich standard. Key components of the framework are the TACO middleware, running on PCs with the Linux operating system, and PLC technology (Simatic S7 PLCs, ET200S decentral periphery and PROFBUS DP) in the front-end. The paper gives an overview of the plans for the new branch lab and explains the Jülich-Munich standard on the base of a typical experiment.

INTRODUCTION

In order to further strenghten 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 SNS in Oak Ridge and at the FRM-II (Forschungsreaktor München II). FRM-II is a new high flux neutron source operated by the Technical University of Munich in Garching near Munich.

As a consequence of the shutdown of its research reactor FRJ-2 (Forschungsreaktor Jülich 2) scheduled for May 2006, JCNS will transfer five neutron instruments from FRJ-2 to the JCNS branch lab at FRM-II and build three new instruments there. All instruments transferred from Jülich to Garching have to be extended and major parts have to be rebuild, because of the higher flux, different geometrical conditions, outdated mechanics and in order to achieve further optimization. All these instruments will get new control and data acquisition systems, since software and electronics typically are older than 10 years.

ZEL (Zentralinstitut für Elektronik), the central electronics facility of Forschungszentrum Jülich, is responsible for the design and implementation of all new control and data acquisition systems for neutron instruments in Jülich. Since the transfer of instruments from FRJ-2 to FRM-II was expected already several years ago, a close cooperation with the instrumentation group at FRM-II was started. Together both defined a common framework for all new control and data acquisition systems of neutron instruments in Jülich and Garching, the so-called "Jülich-Munich Standard", that is followed by most instruments at both sites [1].

Key components of this "Jülich-Munich-Standard" are the consequent use of industrial control technology in the front end and the middleware system TACO, developed by the ESRF for beamline control, on the experiment computers running under Linux [2]. Based on a long term experience in instrumenting Neutron scattering experiments, the ZEL in Jülich concentrated on the development of front end electronics, selection and integration of industrial control technology, development of system software (device drivers,...) and detectors. The instrumentation group in Munich concentrated on application software aspects, especially scripting and extensions of TACO.

INSTRUMENTATION PLANS OF JCNS AT FRM-II

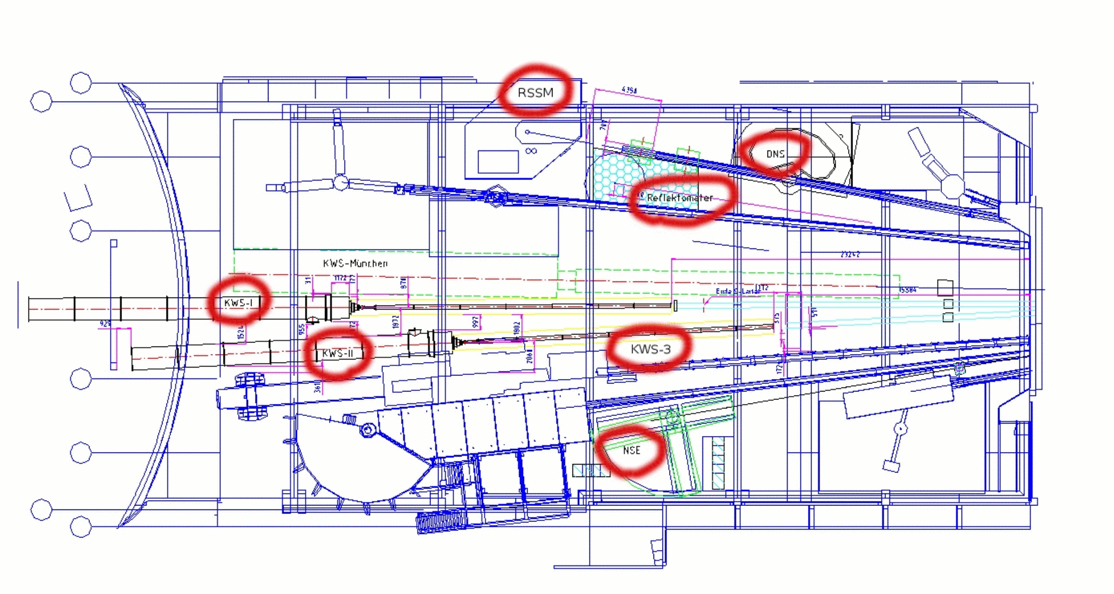

Figure 1: Position of the JCNS instruments in the neutron guide hall at FRM-II

The five instruments listed below, which will be transferred from Jülich to Garching, will undergo major modifications and extensions, caused by new requirements and further improvements, as indicated above. Also, for all instruments new safety systems, e.g. responsible for beam shutter control or vacuum, have to be designed and implemented from the scratch.

As a consequence, also the control and data acquisition systems of those instruments already following the Jülich-Munich-Standard have to be innovated at a major extent.

KWS-1 and KWS-2: Both are classical 40m long pinhole instruments for small-angle neutron scattering, already following the Jülich-Munich standard. For both instruments a new collimation line is under construction. New detector electronics with higher count rates are planned. For the KWS2 an additional high-resolution two-dimensional detector is under preparation. Further plans include equipment for polarisation analysis. Disassembly of KWS-1 and KWS-2 in Jülich will start in October and June 2006, respectively. KWS-1 will start operation at FRM-II in September 2007, and KWS-2 will start operation in July 2007.

KWS-3: KWS-3 is high-resolution small angle neutron scattering instrument with a focussing mirror. Additionally, it supports a reflectometer mode. The control and data acquisition system of KWS-3 is implemented already according to the Jülich-Munich standard. Besides the replacement of the detector electronics, KWS-3 will undergo only minor mechanical changes. Disassembly of KWS-3 will already start in March 2006 and it will become operable again in October 2006.

DNS: The time-of-flight instrument DNS is designed for diffuse neutron scattering and follows already the Jülich-Munich standard. DNS will be equipped with a new shielding, a new monochromator, two new choppers and new position-sensitive detectors. Disassembly of DNS will start in June 2006 and it is intended to start operation at FRM-II in November 2006.

NSE: The Neutron spin-echo spectrometer NSE allows ultra high resolution neutron spectroscopy. Operation at FRM-II requires major mechanical modifications and extensions. Additionally most power supplies will be replaced by new ones with integrated PROFIBUS DP interface. Since the control and data acquisition system is completely outdated and does not follow the Jülich-Munich standard yet, all electronics and software have to be designed and implemented from the scratch. Disassembly of NSE will already start in December 2005 and it will become operable in Garching in March 2007.

The three instruments listed below are new instruments, designed for operation at the JCNS branch lab at FRM-II:

MARIA: For the investigation of layered magnetic structures, the reflectometer MARIA is just being designed. It will include the sample environment of the existing reflectometer HADAS at FRJ-2 in Jülich. It is expected to start operation at the beginning of 2008.

RSSM: The new backscattering spectrometer RSSM is under construction since several years and will start commissioning already at the beginning of 2006.

TOPAS: The thermal time-of-flight spectrometer TOPAS is being designed now and shall start operation in 2009. The instrument TOPAS is not shown in Fig. 1, since it will not be in the Neutron guide hall, but in a new building not yet constructed.

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 the combination of development efforts, the accumulation of expertise and the reduction the number of spare parts on the shelf. Up to now Jülich and Munich have exchanged the development results for many hardware components (motor controller, PROFIBUS controller,...) and software modules (device drivers, TACO servers, configuration software,...)

A guiding principle for definition of the framework was to minimize the development efforts and to acquire as much from the market as possible. Slow control in neutron scattering experiments is related to the accurate movement of a diverse range of mechanical parts, to pressure control and temperature control. Because ZEL introduced industrial control equipment already in the 80s to experiment instrumentation, a key component of the framework is the consequent use of industrial technologies like PLCs, fieldbus systems or decentral periphery in the front end [3]. 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, PID controllers, analog and digital I/O modules, or measurement equipment. For all industrial type of digital and analog I/Os PROFIBUS DP based decentral periphery is recommend. Siemens ET200S is the preferred one. The only motor controllers supported at the field level are the Siemens 1STEP and SMSIPC developed at the University of Göttingen.

Control level: The control level resides above the process level. Devices at the control level are freely programmable. They must meet real time requirements and guarantee robust operation in an harsh environment. The only device supported at the control level is the S7-300 PLC family from Siemens, because it dominates the European market. At the control level two additional motor controllers, the Siemens FM357 and FM351, are supported.

Process communication: Process communication covers the communication of devices at the field and control level with supervising devices 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[4].

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. Server computers near the machine should not be conventional desktop PCs but CompactPCI systems. CompactPCI allows to deploy 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 the TACO has been selected as a 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 an 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 "Python" scripting language 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. In future, it is intended to store measurement data in the NeXus data format, as soon as the instrument-specific aspects of NeXus are standardized sufficiently.

THE CONTROL AND DATA ACQUISITION SYSTEM FOR KWS-3

KWS-3 was the first operable instrument following the Jülich-Munich standard and it serves as a typical example for this approach. Equipment to be controlled includes about 20 movement axes for detector, focusing mirror, sample environment and several apertures. Additional equipment is related to the vacuum system and control of the velocity selector. PROFIBUS DP connection to the server PC is accomplished with a CompactPCI controller board developed by ZEL. The detector is based on a position-sensitive photo multiplier, which is readout with a CompactPCI board developed by ZEL. Also the CompactPCI board reading the monitor counters has been developed by ZEL.

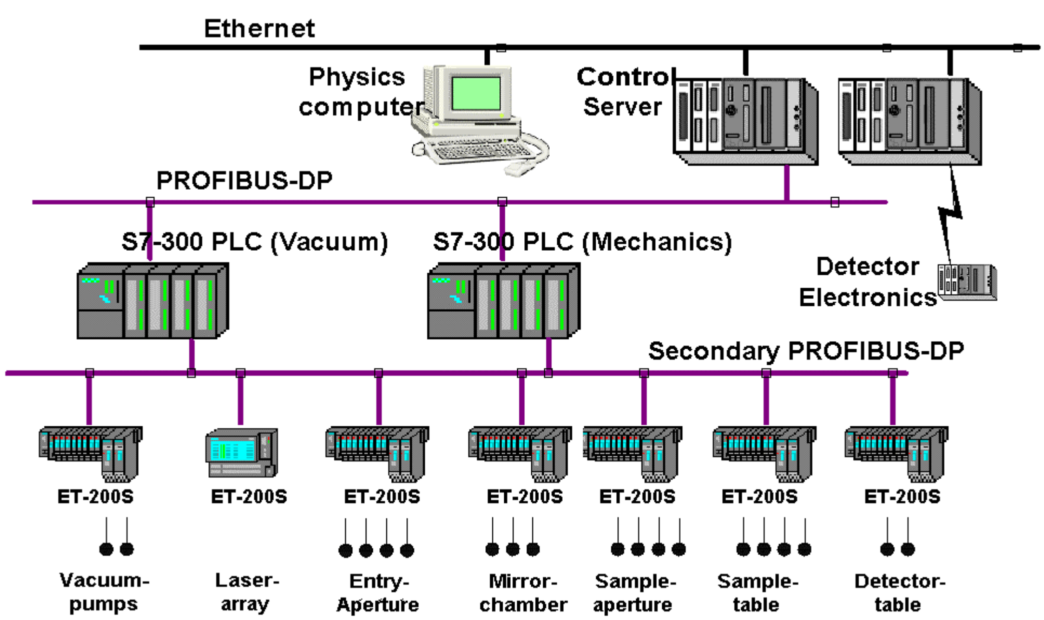

Figure 2: Control system architecture of KWS-3

According to Fig. 2 the control and data acquisition system of KWS-3 is implemented as a distributed system with an hierarchical architecture. On top of the system resides the physics computer where all application software – GUI-based as well as script-based – is running. It is a Linux-based PC, which is configured as a router between the campus-wide network of Forschungszentrum Jülich and the separate Ethernet-based experiment network. Via the experiment network the physics computer accesses two server PCs, residing one common CompactPCI crate. The detector readout controller and the timer/counter board for reading monitor counts and selector speed are directly connected to the CompactPCI bus. But all "slow control" periphery is accessed via a subordinate PROFIBUS segment. Two S7-300 PLC are connected to this segment, one controlling all mechanical movements and one responsible for the vacuum system and velocity selector control. Most motor controllers and position encoders interfaces reside in ET200S decentral periphery systems scattered over the instrument, which are connected to the PLCs via an additional subordinate PROFIBUS segment.

During experiments the instrument executes fully automatic scans, e.g. over sample position or detector position, implemented as Python scripts. A GUI application implemented with Qt allows online visualisation of the detector. An additional GUI implemented with Qt visualizes the mechanical setup of the instrument and allows interactive control of each axis, in order to support service by technical personnel.

CONCLUSIONS

The Jülich-Munich standard provides a modular toolbox, which is able to control virtually all kinds of neutron scattering instruments. The standardized approach limits the number of different components, thus leading to an easier maintainability and an improved development productivity. Nevertheless it is flexible enough to design the user interface of an instrument according to the scientists needs.

The implementation of the control and data acquisition systems of the eight experiments of the JCNS branch lab at FRM-II in less than 4 years, is an extremely ambitious project requiring a major manpower effort. The existence of the powerful toolbox provided by the Jülich-Munich Standard is an important precondition for the success of this project.

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