THE NEW TANGO-BASED CONTROL AND DATA ACQUISITION SYSTEM OF THE NEUTRON SPECTROMETER DNS AT FRM II

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Abstract

Forschungszentrum Jülich has been operating the neutron instrument DNS at the neutron source FRM II for about 10 years. DNS is a time of flight neutron spectrometer with polarization analysis that experienced a major upgrade in 2014 and 2015. During the upgrade DNS was equipped with new electronics and a new control and data acquisition system, including a transition from the existing TACO system to its successor TANGO. On the client side the NICOS software developed at FRM II is used for the implementation of measurement operations and user interface. The design of the new control and data acquisition system is presented and the lessons learned by the introduction of TANGO are reported.

INTRODUCTION

Forschungszentrum Jülich developed and operates about 20 neutron instruments at its outstations ILL in Grenoble, the Spallation Neutron Source in Oak Ridge and at the FRM-II in Garching near Munich. The control and data acquisition systems of almost all these neutron instruments are based on the so-called "Jülich-Munich Standard", a joint effort of ZEA-2 (central electronics institute of Forschungszentrum Jülich) and Technical University Munich (TUM) to define a common framework for the electronics and software of neutron instruments that is followed by most instruments at the FRM-II [1]. It is based on the TACO [2] 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. Because TACO is considered to be outdated now, there was the decision to introduce its successor TANGO [3] at FRM-II as joint effort between TUM and ZEA-2. Since the neutron instrument DNS experienced a major upgrade it was selected as one of the pioneer instruments for the introduction of TANGO, simultaneously with the neutron instrument BIODIFF. At the same time the new instrument control software NICOS (developed by TUM) was implemented on both instruments.

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 recommended. Siemens ET200S is the preferred one. The ET200S modules 1STEP and 1STEPdrive are the predominantly used the stepper motor controllers.

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 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 and PROFINET are the recommended choices. They are the dominating fieldbus systems in Europe and naturally supported by S7 PLCs and many other devices. A major reason for their 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 economic 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

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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 and the data base server. The manager in combination with the data base server operates as a name server, which is consulted by clients to get the actual location of a device 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.

NICOS

NICOS was developed around 2000 at TUM mainly by Tobias Unruh as general purpose instrument control software for neutron instruments at the application level on client computers[4]. It follows a client server approach and uses a consistent object-oriented device model on top of TACO.

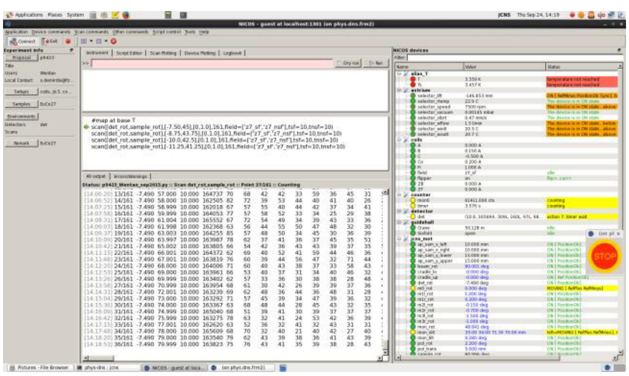

Figure 1: NICOS GUI for DNS.

Recently it has been completely rewritten, mainly by Georg Brandl from Heinz Maier-Leibnitz Zentrum (MLZ) [5]. It experienced major functional extensions, while keeping the essential ideas of the original implementation. NICOS is written in python using pyQt for the GUI. It supports TACO as well as TANGO.

NICOS offers scripting in python and in a simpler command language as well as a configurable GUI for graphical user operation. Functionalities comprise electronic logbook, history plots, detector data plots,…..

Due to its power and flexibility it was decided to use NICOS at all MLZ instruments in order achieve a homogeneous environment for instrument users and to reduce the overall maintenance effort.

BIODIFF and DNS were the first neutron instruments of Forschungszentrum Jülich in the process of replacing the existing instrument control software by NICOS. The NICOS implementation on DNS was done by ZEA-2. Besides configuration issues, extensions for detector readout and data storage had to be implemented. A snapshot of the NICOS GUI for DNS is shown in Fig. 1.

TRANSITION FROM TACO TO TANGO

TANGO is a successor of TACO based on the middleware system CORBA. Contrary to TACO, it is consistently object-oriented and removes many of the deficits TACO had. As an example, it provides generic multi-threading, data caching and proper event handling. Additionally, it comes with many standard tools not available in TACO, e.g. alarm system, logging system, code generators for device servers, process data base, graphical editor for the configuration data base, start up tool.

As a consequence, TANGO is much more complex than TACO and the code base is huge – e.g. it is not possible to compile a complete TANGO distribution on low end front end systems in a reasonable time. Due to the much higher complexity of TANGO, it was clear that its introduction would be a major effort and that performance and stability could be serious issues.

Since TANGO is well-documented and has many structural similarities to TACO, e.g. the device access via functions/methods (contrary to process variable interface of EPCIS), it was relatively easy for developers to get acquainted with TANGO. Even more important, these similarities enabled a quite standardized approach to porting our existing TACO device servers to TANGO, which allowed reusing a major part of the existing code with minimal effort. Tests with simple clients showed a stable behaviour of our TANGO installations with good performance. But in real instruments experiments with NICOS clients we experienced several serious problems:

- NICOS relies on the consistent use of TANGO device states which is different form TACO.
- TANGO device servers are internally multithreaded (one thread per client) leading to problems with our existing code written for the single-threading model of TACO.
- An internal thread serialization timeout of TANGO requires special care in servers for slow hardware.

All these issues could be solved with an additional software effort in the implementation of device servers.

THE DIFFUSE NEUTRON SCATTERING INSTRUMENT DNS

DNS [6] is a versatile time-of-flight diffuse neutron scattering instrument for cold neutrons with polarisation analysis shown in Fig. 2. It is equipped with a supermirror-based polarizer and a large double-focussing monochromator. Lead blocks in the monochromator shielding automatically open in the direction of the outgoing beam, when the secondary spectrometer is

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moved in order to change the neutron wavelength. A failsafe system controlling shutter and lead block movement has been implemented. DNS is equipped with a liftable selector and a chopper system. About 20 mechanical axes with stepper motors are used for variety of slits, movement of sample, detector bank,…

One detector unit for polarized neutrons consists of 24 standard ^{3}He detector tubes and one detector unit for unpolarised neutrons consist of 128 position-sensitive ^{3}He detector tubes.

Figure 2: The diffuse neutron scattering instrument DNS.

THE DNS CONTROL AND DATA ACQUISITION SYSTEM

Physical Architecture of the Control System

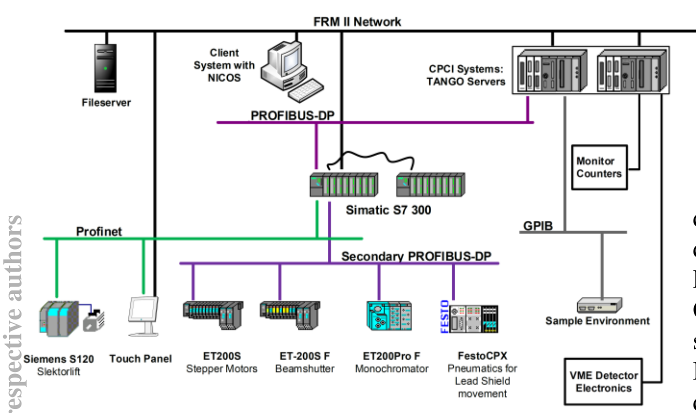

Figure 3: Physical architecture of the DNS control and data acquisition system.

According to Fig. 3 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. Via the experiment network the control computer accesses the "server computers", to which all front end systems (detectors, position encoders, motor controllers, digital IOs, analogue IOs, …) are attached. On the "server computers" TANGO 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 the main S7-300 PLC equipped with the failsafe CPU 319F-3 PN/DP. This CPU contains both the "standard" program as well as the failsafe program for the personal protection in parallel.

Figure 4: Main cabinet with PLC and 3 ET200S systems.

Stepper motor controllers and SSI modules as well as digital and analogue I/Os reside in three modular ET200 decentral periphery systems, which are connected to the PLC via an additional subordinate PROFIBUS segment. One ET200pro failsafe system and one Festo CPX systems are connected to the same PROFIBUS segment. Both modular systems with protection class IP65/67 are directly mounted on the monochromator without any cabinet. All failsafe signals are connected to special failsafe input modules in one ET200S system and in the ET200pro system.

A Sinamics S120 frequency converter for the selector lift drive and a touch panel for local operation of the PLC are connected to the PLC via a subordinate PROFINET segment.

The readout of the 24 standard ^{3}He detector tubes is done via time-stamper modules from Struck Innovative Systeme GmbH in a VME crate, which is connected via a SIS1100 optical link to the server computer. The readout of the 128 position-sensitive ^{3}He detector tubes is not yet

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in routine operation and will be done by a Mesytec MPD system.

Software Architecture

As shown in Fig. 5, the implemented software is distributed between three levels of the system hierarchy. All software below the lower dashed line runs on the PLC in the front end. The software modules shown between the dashed lines are running on the server computers. This comprises TANGO servers and device drivers for dedicated HW modules, e.g. detector electronics, counter/timer board, PROFIBUS controller or GPIB controller. The TANGO middleware is the glue that connects the server computers to the control computer, where the client application programs as well as the TANGO database server (all above the upper dashed line) are running. Since TANGO is location-transparent, the application programs could run on any Linux-based system. The instrument control software NICOS, which internally has a client server architecture, resides as a client on top of TANGO using the pyTango interface.

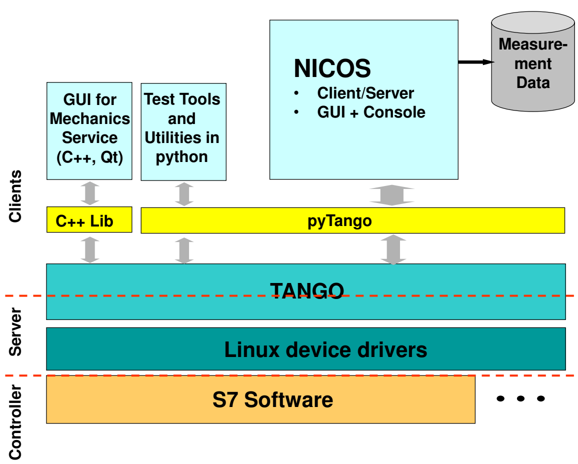

Figure 5: DNS software structure

CONCLUSION AND OUTLOOK

TANGO and NICOS have been successfully implemented in the new control and data acquisition system of the diffuse neutron scattering instrument DNS. After solving problems coming from the architectural differences between TACO and TANGO the instrument is in stable user operation, now.

On the base of the experiences with DNS, TANGO and NICOS will be used for all future neutron instruments of Forschungszentrum Jülich at FRM II and existing TACO-based instruments will gradually be upgraded to TANGO and NICOS in future.

REFERENCES

[1] 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.
[2] A.Götz, W.-D.Klotz, E.Taurel, J.Meyer, J.-L.Pons, M.C.Dominguez (ESRF),TACO manual version 2.1, http://heanet.dl.sourceforge.net/project/taco/manual/2.1/TACO-2.1.pdf .
[3] Official TANGO homepage: www.tango-controls.org
[4] T. Unruh, Instrument Control at the FRM-II using TACO and NICOS, Proceedings of the Nobugs 2002, Gaithersburg, 2002.
[5] E. Faulhaber, G. Brandl, J. Krüger, B. Pedersen, A. Lenz, C. Felder, NICOS – The Instrument control solution for MLZ, Poster at the PCaPAC 2014, Karlsruhe, 2014.
[6] K. Nemkovskiy, Y.Su, S.Demirdis, W. Schweika, A. Ioffe, T. Brückel, DNS – a versatile diffuse neutron scattering spectrometer with polarization analysis at MLZ: present and future, Poster at Deutsche Tagung für Forschung mit Synchrotronstrahlung, Neutronen und Ionenstrahlen an Großgeräten, Bonn, 2014.

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