THE SLOW CONTROL SYSTEM OF THE ATOMIC BEAM SOURCE AT ANKE/COSY – AN INDUSTRIAL APPROACH BASED ON WINCC AND S7 PLCS

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Abstract

For the ANKE experiment at the medium-energy ring COSY at Forschungszentrum Jülich, an Atomic Beam Source (ABS) is under development, which produces a polarized atomic beam (H or D atoms). The necessary front-end equipment for the slow control system consists of more than 100 components, including a variety of vacuum pumps, vacuum gauges, RF generators, valves, leak detectors, temperature sensors, stepping motor controllers, PID controllers, flow controllers, etc. from different vendors. The slow control system should support the routine operation of the ABS as well as experimental tests of the ABS itself.

Safety reasons and economic considerations lead to the decision to use mainly industrial equipment for the slow control system. The Siemens product WinCC – running on a PC under WinNT - has been selected as the core of the SCADA application. The interlock system has been implemented on the base of Siemens S7 PLCs. In order to unify the interfacing to the control computer, all front-end equipment is connected via PROFIBUS DP. Proprietary serial protocols are translated via dedicated gateways.

1 INTRODUCTION

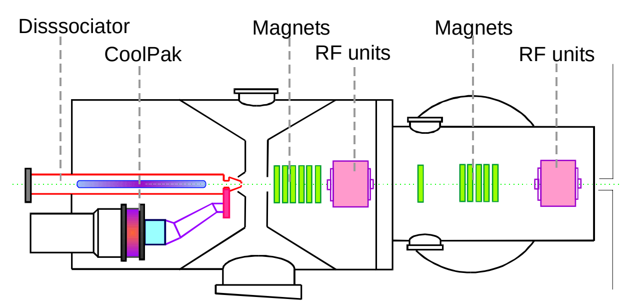
The COSY Atomic Beam Source (ABS)[1] at Forschungszentrum Juelich (FZJ) follows similar operation principles as the existing HERMES ABS at DESY[2]. It has been finished to the extent necessary for first test measurements, e.g. the sextupole magnet system is not yet installed. With regard to control, it is a medium sized system with about 150 process signals and about 15 serial interfaces to more complex devices, at the moment. Many aspects of its final layout are still open, but it is anticipated, that the system will have twice as much components, eventually.

Control systems for accelerators or physics experiments are dominated by "home-made" systems. But PLCs and other industrial equipment are increasingly being used. Especially at CERN there is a strong movement toward global industrial control solutions[3],[4]. Main motivations are:

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

Also at FZJ, the existing control technology is primarily based on homemade systems, e.g. VME systems with a proprietary RT kernel are used in the front end, or SCADA (Supervisory Control and Data Acquisition) applications were developed from scratch as OSF/Motif based programs[5]. Industrial automation technology is used only very reluctantly[6]. The above mentioned reasons require, that future large control systems should be based on industrial automation equipment, mainly. So the medium sized ABS was selected to evaluate the consequent use of industrial control technology.

Figure 1: ABS schematic overview



2 ABS OPERATION

The COSY ABS produces a polarised atomic beam (H or D atoms), which will interact with the protons of the accelerator. A dissociator inside a vacuum vessel produces a hydrogen plasma discharge, in which hydrogen molecules are dissociating. Two RF transition units are used to polarise the atomic beam, which will feed a storage cell. Additional diagnostic systems for intensity measurements (intensity device), measurement of the degree of dissociation (α-device) are temporarily included in the ABS. Interaction of the ABS with COSY control, water cooling, leak detection and the complex movement of the storage cell are still not finalised. According to the schematic view in Fig. 1 the following major building blocks of the ABS are already implemented:

Vacuum system: A differential pumping system consists of seven turbomolecular pumps, three diaphragm pumps and two cryo pumps. Valves can control several bypasses between the four stages of the vacuum vessel. Pressures are monitored by 8 vacuum gauges attached to three MKS 146 C control units. Also temperatures are monitored.

Dissociator: The dissociator includes an industrial RF generator from Hüttinger for the plasma discharge as well as flow controllers for the O_2 and H_2 gas supply. The dissociator nozzle is cooled via a heat bridge to a cold head (Leybold CoolPak). Two heaters, which are controlled by individual PID loops, are responsible for the temperature stabilisation of cold head and nozzle.

Intensity device: For absolute intensity measurements a calibration system for a reference pressure was implemented that includes a vacuum pump, two flow controllers, ten valves and a manual operation panel. [7]

α-device: This diagnostic instrument measures the degree of dissociation. Equipment includes a chopper and a quadrupole mass spectrometer. [8]

The control system had to be continuously modified during the development process. The main building blocks of the future development phases will be:

Hyperfine transition units: rf units being under development at the University of Erlangen have to be installed into the source. They will produce the desired polarisaton of hydrogen and deuterium atoms.

Water cooling: Separate water cooling systems have to be installed for the cryo pumps, turbo pumps, RF generator and the dissociator. This includes leak detectors, valves as well as sensors for pressure, temperature and flow.

Storage cell: The storage cell temperature has to be controlled. The storage cell should probably be retractable from the COSY beam orbit in order to facilitate tuning of COSY for other experiments. This may even require movement of ANKE detectors.

Still many aspects of safety related interlocks and connection to the COSY control system are open.

3 MAJOR BUILDING BLOCKS OF THE SLOW CONTROL SYSTEN

3.1 Basic Design issues

The ABS is an appropriate candidate for the consequent application of industrial control technology, because it has safety relevant aspects requiring the application of robust industrial PLC technology for the basic interlocks. With regard to control it is a typical slow control system with moderate timing and data throughput requirements. Since the expected number of process I/Os was in the order of a few hundreds, it seemed to be sufficient to base the control system on a single PC, but this should be extendable. Additional boundary conditions were man power restrictions, requiring powerful development tools. Since the specification for the ABS was still evolving and subsystems should be tested individually, a high degree of flexibility was required from the development tools.

Basic design decisions are related to front end PLC and I/O systems, the communication technology and the toolkit for the SCADA system . These three basic building blocks determine flexibility, extendability and scalability of the system, as well as development productivity and the overall economics. The following sections introduce and motivate our selections.

3.2 PROFIBUS

PROFIBUS, being a national German (DIN 19245) and an European (EN 50170) standard, has become the most widely accepted modern fieldbus technology in Europe[9]. It is expected to take a similar role on the world market, since the IEC standardisation efforts for a common international fieldbus failed recently. A major reason for its success is the technological and functional scalability based on a common core. Now, a wide range of PLCs as well as low cost process I/Os is available from a variety of manufacturers which enable easy interfacing.

Most of the installed PROFIBUS equipment follows the profile DP (decentral periphery), which has been designed for the optimised connection of simple, low cost I/O in a time critical environment. Basically, a DP system transparently maps process I/Os to a dual ported RAM in the host system. So PROFIBUS DP is now used by ZEL as the common, integral path from controlling computers to industrial equipment in the front end[10]. ZEL tries to use commercial PROFIBUS equipment wherever possible, but some existing gaps had to be filled by own developments, e.g. PROFIBUS controller for CompactPCI, or PROFIBUS driver and configuration software under Linux and LynxOS[11]. For the ABS only commercial components were used. The only exception is the serial gateway introduced in subsection 3.5.

3.3 S7 PLCs

S7 PLCs are the newest product line from Siemens. Siemens has been selected, because it is the dominating manufacturer of industrial automation equipment on the European market. Additionally, the S7 series comes with powerful development and diagnostic tools. A big variety of modules is available, also complex function modules (position controllers, PID controllers, etc.). PROFIBUS is the well supported natural method of external connectivity. PLC periphery can be transparently extended by ET200 type of distributed I/Os. The S7 series is scalable, but we are using only 315-2 CPUs.

3.4 WinCC

Main functions of the ABS SCADA software are

- Monitoring (visualisation of the process state and history)

- Operator control (set parameters, switch on and off subsystems or operations, acknowledge alarms)
- Archiving of process variables and alarms
- Communication with the process periphery and supervisory computers (e.g. ANKE DAQ)

Because of our man power restrictions, our main requirement was the availablity of powerful development tools for the SCADA software in order to increase development productivity. Additionally we required a high degree of flexibility, because we expected frequent changes of the system during the development and test phase. A natural support for S7 PLCs and PROFIBUS DP would be favourable.

So it was clear that the classical development from the scratch (e.g. using Qt and pure C++) was no serious choice. Also “Lab automation” tools like LabView were not considered, because they typically have no internal database or predefined alarm system and have a quite obscure graphical programming environment. EPICs was felt to be too big and the binding to VxWorks was considered as a major disadvantage. Support for PROFIBUS DP was expected to be insufficient. As a consequence we decided to acquire an industrial windows based package from the market, like e.g. Wonderware’s InTouch. The Siemens product WinCC was selected because of support, long term availabilty and the natural integration of PROFIBUS DP and of several proprietray protocols for accessing Siemens PLCs. Main components of WinCC are

- Graphical editor: Process pictures can be drawn comfortably and the attributes of graphical objects can be connected to process variables transparently
- Database: WinCC integrates SYBASE for the storage of process values and alarmes.
- Alarm system
- Variety of channel DLLs to support a lot of industrial networks and PLC types

WinCC is a PC based system that runs only under Windows NT/98 and offers most of the “open” interfaces (ODBC, OPC, DDE, OLE,...) found in a Microsoft environment. It can be structured as a client/server-system, but the server functionality can not be distributed.

3.5 Serial Gateway

As a spin off from an industrial project, a DP slave was developed, that is equipped with 8 serial channels, supporting RS232 and RS485. As usual, the controller core is implemented as an intelligent subsystem according to Fig. 2, with a central address/data/control bus connecting the CPU MC68340FE16, 512 KByte FlashEPROM, 256 KByte of static RAM and the protocol chip SPC4.

An embedded application software on the MC68340 implements those parts of the serial protocols for Pfeiffer vacuum pumps and MKS 146C control devices for vacuum gauges, that are required by the ABS application. So the system serves as a gateway between these serial protocols and PROFIBUS DP. Via this gateway, the process control computer can directly access pressures, status, set points or rotation speeds in the DP image, thus offloading protocol handling and polling operations to the gateway.

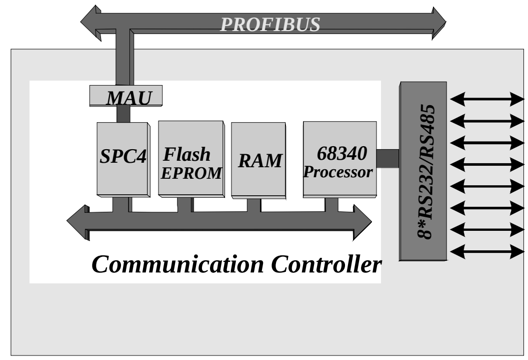


Figure 2: Block diagram of the serial gateway

4 CONTROL SYSTEM ARCHITECTURE

According to Fig. 3, there is one central control computer, a PC running Windows NT with WinCC. So process database and operator interface are on this machine. All process I/O is connected via PROFIBUS DP. Temporarily, some “laboratory type equipment” is attached via GPIB. For the connection to ANKE DAQ, a simple protocol based on XDR and UDP has been implemented, that allows the transparent access to internal WinCC tags via Ethernet. Thus ANKE DAQ can download setups to the ABS and continuously read back its status for inclusion in the data stream. The same protocol is used by a physics workstation for experimental tests of the ABS itself.

Process equipment includes three S7-300 PLCs, one for the vacuum system, one for the intensity device and one for chopper control, cold head temperature stabilisation and for the hyperfine transition units. A fourth PLC is under preparation for leak detection and water cooling.

A RF generator manufactured by Hüttinger as well as two serial gateways are directly attached to PROFIBUS DP. Temperature stabilisation of the dissociator nozzle is done in software by a WinCC script, at the moment. The necessary process I/O is done via ET200S distributed I/O. Also an ET200L system is directly attached to PROFIBUS DP, which controls a wire monitor for beam profile analysis.

Because the ABS is continuously changing during the development and many aspects of its final slow control structure are still open, the control software is still evolving and can be considered as a prototype. Operator interface includes editing of most parameters, command buttons for vacuum and dissociator control as well as textual or graphical display of all relevant process values.

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