IMPLEMENTATION OF FAIL-SAFE SUBSYSTEMS FOR THE CONTROL SYSTEMS OF NEUTRON SCATTERING EXPERIMENTS

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Abstract

Control systems for neutron scattering experiments typically contain subsystems where machine or personnel protection is required, e.g. in vacuum systems or beam shutter controls. In future developments of Forschungszentrum Jülich, the classical implementation of these subsystems with electromechanical components will be replaced by the use of intelligent devices like special fail-safe PLCs, With the new approach Category 3 according to EN954 can be achieved, even for distributed implementations with interconnections via standard fieldbus systems. RSSM is the first experiment, where safety mechanisms are implemented according to the new approach. It is a neutron backscattering spectrometer, that is being build by Forschungszentrum Jülich at the new high flux neutron source FRMII near Munich.

INTRODUCTION

As a consequence of the planned shutdown of its research reactor FRJII (Forschungsreaktor Jülich II) scheduled for Summer 2005, Forschungszentrum Jülich founded the branch laboratory JCNS (Jülich Center of Neutron Science) at the FRMII (Forschungsreaktor München II). FRMII is a new high flux neutron source operated by the Technical University of Munich in Garching near Munich. Forschungszentrum Jülich will transfer seven neutron instruments from FRJII to JCNS and build one completely new instrument, the back-scattering spectrometer RSSM (Rückstreuspektrometer München). Also major parts of all instruments transferred from Jülich to JCNS have to be rebuild, because of the higher flux, different geometrical conditions and outdated mechanics. For most instruments completely new software and electronics have to be implemented, since both typically are older than 10 years. An important issue is the implementation of those software and hardware subsystems that are responsible for machine or personal protection, e.g. beam shutter controls. Here the classical approach based on safety relays will be abandoned in favour of special fail-safe PLCs in order to achieve increased flexibility and better diagnostics.

THE JULICH-MUNICH STANDARD

ZEL (Zentralinstitut für Elektronk), 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 Jülich to FRMII was expected already several years ago, a close cooperation with the instrumentation group at FRMII was started. Together both defined a common framework for all new control and data acquisition system of neutron instruments in Jülich and München, the so-called "Jülich-Munich Standard", that is already implemented in several instruments at both sites [1]. The definition of this framework was motivated by combining development efforts, creation of know how pools and reducing 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,...).

Key components of this "Jülich-Munich-Standard" are the use of PCs with Linux on the supervisory and on the server level, with the middleware system TACO conncecting both levels. TACO has been developed by the ESRF for beamline control [2].

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, another key component of the framework is the consequent 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

Since Siemens is the dominating supplier for PLCs in Europe, the front-end systems being build by ZEL are based on Siemens products, especially S7-300 PLCs and ET200S decentral periphery connected via PROFIBUS.

IMPLEMENTATION ISSUES FOR FAIL-SAFE SYSTEMS

In Europe, safety of automation systems is addressed by the EU machinery directive 98/37/EC and the Seveso II directive 96/82/EC. The Seveso II directive is relevant especially for the Process industry whereas neutron instruments are supposed be addressed by the machinery directive. The standard EN954, which is part of the harmonised standards of the machinery directive is concerned with the safety-related components of machine controllers. EN954 does not specifically address programmable electronic devices and defines a mechanism for risk analysis leading to safety categories that have to be fulfilled. On the other hand the international standard IEC61508, which is concerned with the functional safety of programmable electronic safety-related systems, is not harmonised under the machinery directive.

For safety-related components FRMII requires at least an implementation according to Category 2 of EN954. In addition for each neutron instrument a so-called "instrument box" is required, which servers as the interface to the reactor. It provides analog and digital I/Os for status information and digital I/Os to request the closing of beam shutters. To be on the "safe" side, ZEL aims even at Category 3 of EN954 for all systems implemented at JCNS.

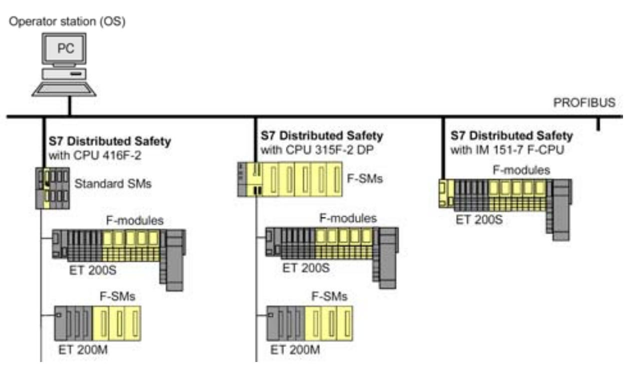

Figure 1: Configuration Example of Siemens S7 Distributed Safety [3].

In industrial system the conventional safety relay technology which causes restrictions regarding flexibility, engineering cost and diagnostics availability is being replaced by special fail-safe PLCs and I/Os, which even may be interconnected via safety fieldbus systems like PROFIsafe or SafetyBUS p [4]. Typically, in a safety fieldbus system, a standard fieldbus (e.g. PROFIBUS) is extended with a special safety application layer. Thus safety devices and standard devices can coexist on the same bus. Fail-safe systems are applicable for the control of processes with a safe state, that can be reached immediately after shutdown.

Fail-safe PLCs are available from a variety of vendors, some of them being specialised on safety PLCs, e.g. HIMA or Pilz. ZEL has decided to use the Siemens "Distributed Safety" approach according to Fig. 1 for fail-safe systems, since the standard process-periphery of instruments are based on Siemens S7-300 PLCs and on ET200S decentral periphery. The scalability of the approach, the use of existing engineering tools, the possibility to mix fail-safe components and standard components is a major advantage of this approach.

In a "Distributed Safety" system, a special fail-safe CPU (S7-300 or ET200S) is required, which monitors itself to detect faults autonomously. On this CPU a standard PLC program and a safety program can run simultaneously. The safety program has to be implemented in a special subset of FBD (function block diagram) or LAD (ladder diagram). Safety-related signals are connected to fail-safe I/O-modules which are internally redundant and can detect internal and external faults. Standard modules and failsafe modules can be mixed in the same PLC. Also decentral extension with ET200M or ET200S via PROFIsafe is possible. Up to Category 4 of EN954 can be achieved with "S7 Distributed Safety".

THE CONTROL SYSTEM FOR RSSM

The backscattering spectrometer RSSM is under construction in the neutron guide hall of FRMII. The backscattering technique allows for highest energy resolutions because monochromators and analysers are hit perpendicular to the crystal plane, where angular errors have the least influence. The energy of the incident neutron is modulated by the moving monochromator (doppler drive shown in figure 2). A further optimisation is achieved by the PST(phase space transformation)-chopper, which makes a wider part of the neutron spectrum usable to the instrument. The stepper motor driven ELREBO (element replacement box) serves as a local beam stop.

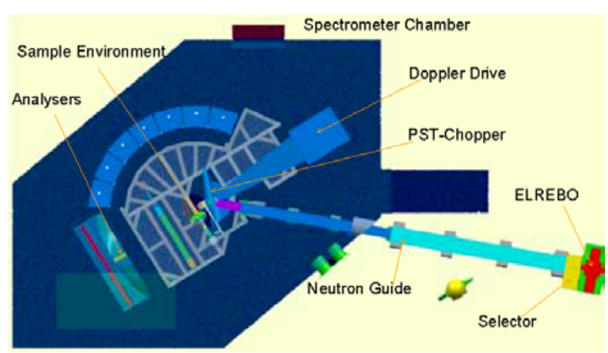

Figure 2: Geometrical Layout of RSSM.

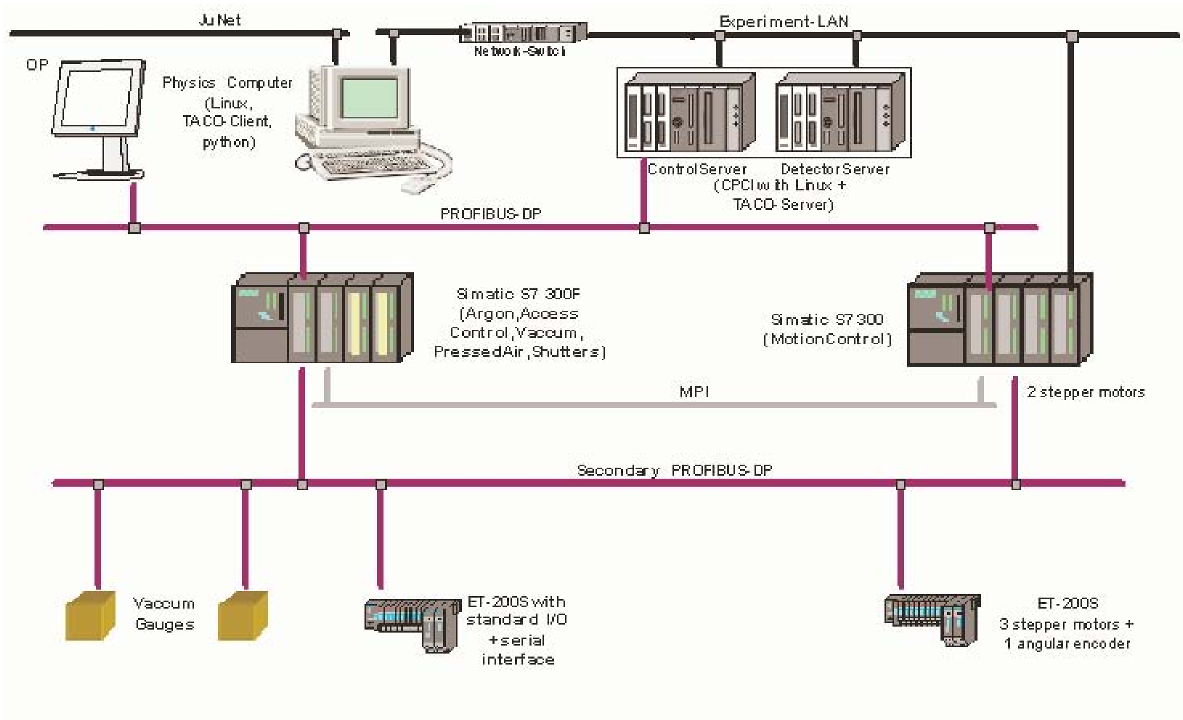

Figure 3: Structure of the control and data acquisition system of RSSM.

PST-Chopper and the platform for doppler, detectors and sample can be moved independently. Additional axes are provided for sample environment and an aperture. Further control issues are related to vacuum for ELREBO, Chopper, selector and neutron guide.

Figure 4: Fail-safe PLC S7-300 of RSSM.

The spectrometer is filled with Argon, which will be activated by the neutrons. So the Argon must not leave the spectrometer chamber before a predefined time, to insure that the radioactivity has decreased sufficiently. To keep the Argon pure, the pressure in the chamber must be slightly higher than the air pressure. So safety issues are related to

- filling/removal and pressure regulation of Argon,
- access control to the spectrometer chamber,
- control of the ELREBO,
- interface to the instrument box,
- control of pressed air (avoid over-pressure in the chamber)

According to Fig. 3, there are two PLCs in the control system of RSSM connected via PROFIBUS to a server PC. One PLC is responsible for all mechanical axis movement. The other one is responsible for the safety-related issues and all remaining slow control tasks. The photo of this PLC shows that it consists of the fail-safe CPU S7-315F with standard modules and fail-safe modules. The safety program is being implemented now. Commissioning of the system is planned in June 2005.

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