# THE NEW CONTROL AND INTERLOCK SYSTEM FOR THE SPS MAIN POWER CONVERTERS

B. Denis, P. Malacarne, Ch. Mugnier, CERN, Geneva, Switzerland
J. Varas, GTD, Barcelona, Spain

*Abstract*

The Control and Interlock System (CIS) of the SPS main power converters was designed in the mid-70s and became increasingly difficult to maintain. A new system based on Programmable Logic Controllers has been developed by an external contractor in close collaboration with CERN. The system is now operational and fully integrated in the SPS/LEP control infrastructure. The CIS is the first major contracted industrial solution used to control accelerator equipment directly involved in the production of particle beams at CERN. This paper gives an overview of the SPS main power converter installation and describes both the contractual and technical solution adopted for the CIS. It first explains how the system was specified and how the contractual relationship was defined to respect CERN's purchasing rules and the operational requirements of the SPS accelerator. The architectural design of the new system is presented with special emphasis on how the conflict between safety and availability has been addressed.

## 1 INTRODUCTION

In the SPS accelerator, commissioned in 1976, the particle beam is maintained on a circular path by a magnetic field produced by 744 dipole magnets. The cross-section of the particle beam is maintained by a system of 216 quadrupole magnets, alternatively focusing and defocusing. The main dipole and quadrupole magnets are fed by 17 power converters. The power converters together with the associated 18kV substation constitute the so-called SPS Main Power Converters [1].

The distribution of the power converters around the SPS[1] carries many risks related to personnel and equipment safety. The Control and Interlock System (CIS) is in charge of the detection of the faults in the SPS main power converters and the associated equipment. It stops the relevant power converters and switches off the appropriate circuit breakers so as to guarantee human and material safety. In addition, the CIS allows both a local and dedicated control of every single converter and a remote and coherent control of the complete installation.

The Control and Interlock System was obsolete. It was decided to build a completely new system based on industrial solutions and to contract-out the major part of the development to industry. A new system based on Programmable Logic Controllers (PLC) has been developed by GTD, a Spanish software company. This system is completely integrated in the SPS/LEP control system and uses active redundancy hardware loops developed at CERN. It is now in its second year of operation.

This paper shortly presents the contractual approach used for the CIS project. It describes the technical solutions and highlights the key design characteristics.

## 2 THE CONTRACTUAL APPROACH

### *2.1 Technical specifications*

The technical specifications [2][3] were based on ESA PSS-05 software engineering standards [4]. The documents covered functional requirements and non-functional requirements with a particular emphasis on safety and availability. Clear project phases and milestones were also specified. The specifications were organized so as to allow requirement tracing during the development process.

The specification documents were also aimed at providing the contractor sufficient material to estimate the development cost and to minimize the risk associated with the 'lowest bidder' rule specified by CERN's purchasing rules. A special effort was however made to avoid being too prescriptive to allow the contractor to use its competence and creativity to develop the solution.

### *2.2 Collaboration between CERN and GTD*

CERN was much involved during the execution of the contract. The role of CERN was however not limited to the control of the development. A genuine collaboration between CERN and GTD based on a mutual effort to understand the other party's problem was set up.

The involvement of staff members in the project reviews was also aimed at providing the necessary knowledge to

[1] The SPS circumference is about 7km.

diagnose problems during the future operation and the maintenance of the system.

## 3 OVERVIEW OF THE NEW SYSTEM

### *3.1 Layout and environment*

The overall layout and the environment of the CIS are presented in Figure 1.
The system is composed of 19 industrial PLCs (Siemens 31x serie) communicating via a dedicated fieldbus (Profibus) and interconnected to the SPS/LEP control system through a gateway based on an HP workstation.
Every power converter has its own PLC in charge of the local fault detection and safety reaction. These PLCs also provide local control of the power converters. Similarly a PLC is dedicated to the main circuit breakers located in the 18kV substation (BE building).
An additional PLC, the so-called Master PLC, provides co-ordination between the PLCs, implements global control and ensures safety at the global system level.
The gateway allows the integration of the CIS in the SPS/LEP control system. In particular, it implements an SL-Equip equipment server [5], allowing application software to interact with the CIS, and sends alarms to the CERN Alarm System [6].
The CIS works in conjunction with the Hardware Interlock Loops (HIL) system. The HIL is an active redundancy developed for safety purposes by CERN in the frame of the CIS project. It provides the CIS with direct links to major safety elements and is composed of simple devices such as relays and optocouplers linked together by multi-core cables.

### *3.2 Development tools and methods*

The whole system analysis and design was performed using OMT object-oriented methodology. This required an extra effort to introduce the method for the analysis of PLCs since they do not support some of the programming structures used by object-oriented techniques.
C++ was chosen for UNIX applications, that is the gateway and man-machine interfaces installed in the SPS/LEP control system. The programs for the PLC's were developed in SCL, an International Electrotechnical Commision (IEC) structured language.

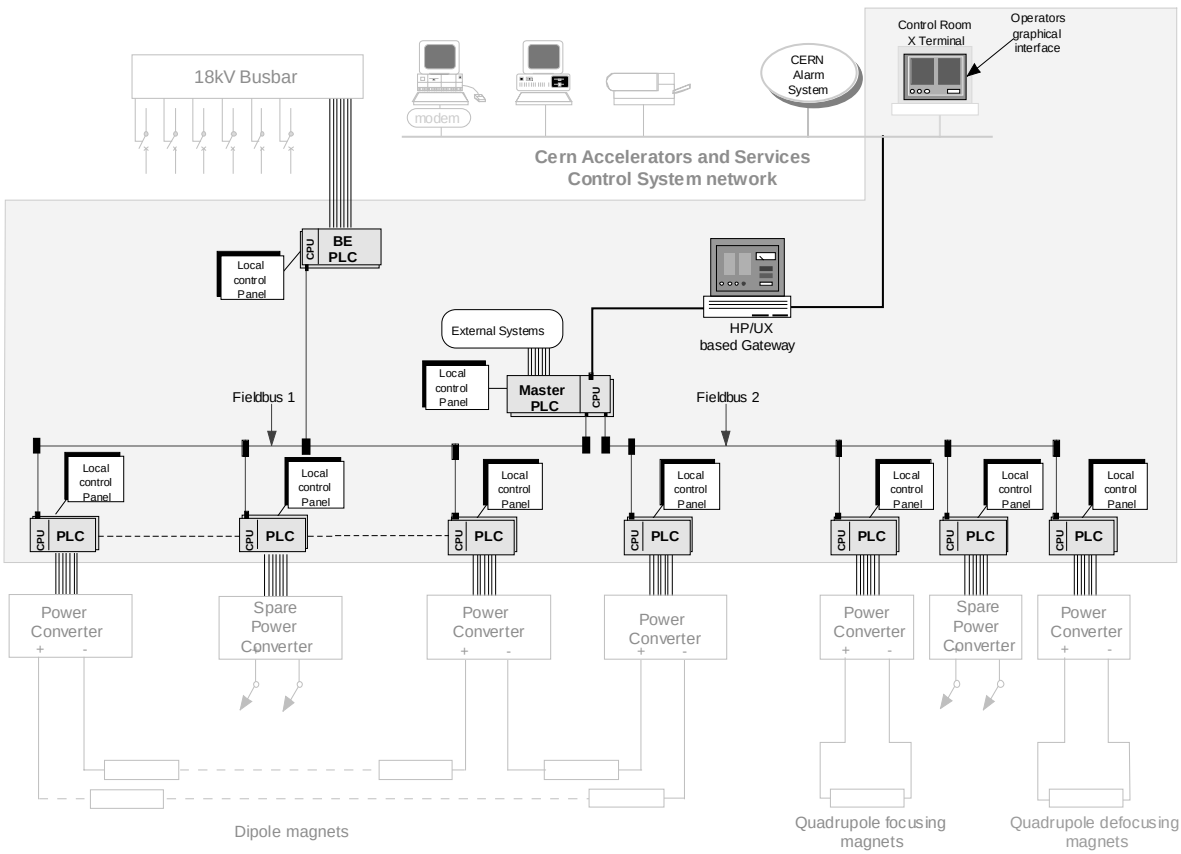


Figure 1: New Control and Interlock System Layout and Environment

## 4 ARCHITECTURAL DESIGN

The main technical challenge was to develop a system meeting strict and conflicting requirements: safety and performance. The result is a highly configurable system with a dual philosophy: distributed safety and centralized control.
Specific design solutions have also been developed to provide the operators with a valuable retrospective analysis tool. A special design effort has also been made to maximize the availability and build a highly adaptable system.

### *4.1 Distributed safety*

From the safety point of view, the system is fully distributed with bottom-up safety reaction sequences.
Each PLC is responsible for the safety of its associated power converter. The time between the detection of a fault and the reaction is kept under 5 ms. This performance is made possible by having predefined reactions for each type of fault.
Fault detected at local level are reported to the Master PLC which triggers reactions related to the global safety of the main power converters within 100 ms.

### *4.2 Centralized control*

From the control point of view, the system is centralized. The Master PLC co-ordinates any actions on the main power converters and deals with the multiple safety constraints.
User commands are implemented as complex sequences of local commands possibly associated with safety pre-conditions. This mechanism allows the implementation of very sophisticated commands.

### *4.3 Information flow*

The dual concept of distributed safety and centralized control is also embedded in the communication layer developed on top of the Profibus standard. This protocol layer guarantees a fixed bandwidth for safety related data while providing an adjustable communication path for other data—equipment status, configuration data and command execution requests.

### *4.4 Events time-stamping and synchronization*

Detected faults are time-stamped early during the safety reaction mechanisms to allow a local precision of 0.1 ms.
Post-mortem analysis of these events is only possible if the PLCs are properly synchronized. A specific mechanism using the services of the SPS timing system has therefore been developed. Each PLC receives the Start of SuperCycle (SSC) event and, at regular time intervals, the Master PLC broadcasts the time corresponding to the last SSC received and asks the other PLCs to synchronize.

### *4.5 Availability*

The system has also been designed so as to allow the main power converters to run in case of failures in the SPS/LEP control system or in the gateway. Moreover the distributed CIS architecture tolerates temporary communication losses on the fieldbus.

### *4.6 Maintainability*

In addition to the effort to produce maintainable code using object-oriented practices, the system has been designed to be highly configurable. In particular, new fault detection can be easily added and command behavior is (re)configurable.

## 5 CONCLUSIONS

The CIS system has been delivered on time and within budget in March 1998. The technical competence of GTD and the quality of the specification have been key factors explaining the success. We also believe that the quality of the relationship and the true collaboration between CERN and GTD were sine qua non.
The system has proved to be very reliable. New functions have been implemented during the 1998/1999 winter shutdown demonstrating that the system is extendable.
Finally, the new retrospective analysis feature has also allowed the people in charge of the main power converters to gain understanding of the overall behavior of the power converters.

## REFERENCES


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