TRENDS IN INDUSTRIAL CONTROL SYSTEMS IN ST DIVISION AND AT CERN

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Abstract

Since the 1970s, industrial systems have been introduced in ST Division and have formed the basis for the overwhelming majority of the equipment for which it is responsible. The first systems were independent and not integrated into the accelerator control networks. This first generation included the Technical Control Room (TCR) site and networks monitoring system supplied by *Télémécanique*. In 1980, this system was replaced by the BBC and the Landis & Gyr systems for the cooling and ventilation equipment. In 1979, the Sprecher & Schuh system for the control of the electrical generator sets (with CERN's first PLC) was installed. Since the 1980s, these systems have been gradually integrated, initially using G64s as the interface with the PLCs, then, with the introduction of FactoryLink to handle H1 communications based on TCP/IP and, finally, with the Technical Data Server (TDS) and the TCP/IP communication replacing H1.

1. INTRODUCTION

The terms of reference of ST Division (formerly SB) have always included the design and operation of equipment relating to CERN's technical infrastructure. This equipment is not specific to CERN but is generally to be found in industry.

As a direct consequence, industrial control systems have been used as soon as they emerged.

1.1 DCS (Distributed Control Systems)

The first system was installed in 1970. This was a Télémécanique system consisting of a central T2000 computer and 20 distributed stations with mainly data acquisition functions (status, measurements, counters). Its purpose was to centralize supervision, via the TCR, of the electrical and fluids networks, technical equipment, and the safety systems. In the 1980s, this system was replaced by the BBC-BECOS30 system with the subsequent back-up of the Landis & Gyr Visonik system which centralized cooling and ventilation equipment monitoring.

These were closed DCS systems with proprietary protocols.

1.2 PLC (Programmable Logical Controllers)

The first PLC in service in the Division, and probably at CERN, was a SESTEP installed by Sprecher & Schuh in 1979 to control the electrical generator sets of the Meyrin power plant.

A second series of PLCs was commissioned in 1983 to control the SPS pumping station. This has been followed since 1985 by several further applications (Fig. 7 "Annual PLC installation at CERN").

2. INTEGRATION

In 1989, the Monitoring and Communication Group of ST Division (ST/MC) and the Controls Group of SL Division (SL/CO) reached an agreement on a common integration and mutual collaboration policy.

In addition to any rationalization or synergy motives, the specific grounds for this decision were twofold:

- the commissioning of LEP which imposed the need for a rationalization of the communication networks, given the distances involved,
- the integration into the TCR of systems from other divisions.

The systems were integrated gradually, starting with the lowest layers. To illustrate this development, a number of systems are described below.

2.1 SPS Demineralized Water Distribution System
(ST/CV and ST/MC collaboration)

This was the first integrated system in the SL/CO control network and supervised by the TCR.

Integration is achieved via a link between the Siemens PLCs and the G64s serving as a gateway to the SL/CO network. The system is supervised from the TCR via the standard Unified Man Machine Interface (UMMI) based on Data View [2].

2.2 Industrial control integration in the TCR *(Figure 1)*
(ST/CV and ST/MC collaboration)

Siemens PLCs have been increasingly used since 1993 and, in conjunction with the industrial supervisor FactoryLink, integrated in the existing control system for the supervision of four different systems.

2.2.1 Safety Applications

Starting with the Chorus and Nomad safety system, the application is currently extending to the global safety systems at CERN using the above-mentioned system. The system includes fire and gas detection, emergency stop equipment and other safety-related data. The system comprises around 2500 data points controlled by 15 different PLCs around the site and serves the Fire Brigade Control Room.

2.2.2 Cooling Water of the West Area

The cooling water circuits servicing the CERN West Area are controlled by two PLCs, programmed and supplied by an outside firm. The field bus used for the previous safety system was extended to include these two PLCs. The communication functions for the PLCs were provided by CERN to ensure compatibility. The TCR monitors approximately 300 data points from this system.

2.2.3 Cooling Circuits of the PS Accelerator

The Proton Synchrotron (PS) had its cooling water control systems entirely rebuilt in the period 1994-95. The project was given to an external firm which was required to deliver a SINEC H1 connection to an HP machine running FactoryLink. The accelerator comprises 15 cooling stations controlled by PLCs connected to a concentrator by two separate field buses using SINEC L2 protocol; the PLC is itself connected to FactoryLink running on the HP machine using the SINEC H1 protocol over Ethernet. Due to the large number of equipment parameters controlled and the relative stability of the system, an event driven data acquisition system was implemented. The TCR monitors approximately 1000 points from this system.

2.2.4 Cooling Circuits for the Computer Centre

In 1995, the CERN Computer Centre cooling circuits were provided with new control facilities. Connecting the Computer Centre PLC to the existing SINEC L2 network for the PS cooling made the integration of this system possible. The TCR monitors 120 points from this system.

Main System Characteristics

- 4000 points monitored,
- 32 Siemens S5 - 115-U PLCs,
- HP Server running FactoryLink and in-house alarm and HCI interface. Presently, the HP Server runs an EC (Equipment Controller) communicating with TDS (Fig. 4).

2.3 SPS Access Control and Machine Interlock *(Figure 2)*

2.3.1 Introduction and definitions

The safety of personnel entering the accelerator, which entails radiation and electrocution risks, is provided by the Access Control System that conforms to the following rules:

- All equipment related to beam circulation can only operate when nobody is inside the machine.
- Personnel are only allowed to enter the machine when dangerous beam circulation equipment is not in operation and radiation is at a safe level.

Considering the above rules and the related consequence, the design of the access control system consists of two complementary functional blocks: the Access and Search Interlock System (A&S) and the Machine Interlock System (MIS).

The purpose of the SPS Access and Search Interlock System is to control the different access equipment (doors, separating grids, shielding doors, etc.), of the various buildings and sectors of the tunnel.

2.3.2 Architecture

The complete Access Control System of the SPS is based on the tight integration, at the “Safety Desk” level, of the A&S and MIS systems.

The A&S and MIS systems have the same logical structure, based on local PLCs (managing local interlocks) which communicate to a central controller (managing central interlocks) through dedicated SINEC L2 branches.

The central controllers exchange summary data with a master PLC located within “Safety Desk” of the SPS-LEP control room (PCR) using the SINEC H1 protocol. The master controller manages the integration of the A&S and MIS through the “resultant master interlock chains”.

The flow of information, through SINEC H1 and L2, can be summarized as follows:

- the central controllers receive “commands” from the FactoryLink supervisor and dispatch them to the local controllers;
- the central controllers receive “statuses” from local controllers, dispatch them to the HP and process them in order to provide the master controllers with their respective resultant interlocks chains.

Each system has its own hardware redundancy for data exchange between local, central and master controllers.

The global system is also equipped with a dedicated “Service Network” based on RS-232 lines for contingency reasons, connecting the master controller to industrial PCs into the local sites. This network is used to distribute the “Access” database.

Main System Characteristics

- 130 access elements (doors, grids, turnstiles, key distributors, search boxes, etc.),
- 600 keys (access and safety keys),
- 15 film-badge readers (Bar Code reader),
- 50 accelerator equipment (magnets, RF systems, dumps, etc.) for interlock functions,
- 26 Siemens S5-115-U PLCs,
- 1 SINEC H1 network,
- 6 SINEC L2 networks (up to 5 km),
- HP-UX FactoryLink (V. 4.3.1) application software.

System operator supervises the access system on workstations connected to an HP server running FactoryLink. This server is connected via the SINEC H1 network to the master PLC.

2.4 CERN Site Access System *(Figure 3)*

A CERN-wide site-access system is being installed in three phases: first, at 12 local access sites around the SPS accelerator, then, at 10 local access sites on the Swiss Meyrin area, and the last phase will be at 17 local access sites around the LEP Collider.

Each remote site communicates by TCP/IP over the controls network via a local HP-UX computer that runs a proprietary supervisor and acts as a gateway between the local cluster of PLCs and the central access control room. At each site, the local PLC cluster interfaces to gates, doors, badge-readers, lights, etc.

Each site is controlled remotely, but is also capable of operating autonomously in stand-alone mode, should a network problem occur. To allow local operation, each site holds a subset of the central data-base of persons authorized to access a particular site.

At the central control room, one finds HP-UX workstations running Java application and a global access server. The site access system consults a central CERN personnel database to obtain individual access authorisation. Alarms, generated at the local sites, are sent for analysis to the central alarm server and for presentation to the site access operator.

The system manages all video matrix, enabling the central control room to overview all the sites.

2.5 SPS Smoke Detection and Ventilation Systems *(Figure 4)*

The SPS smoke detection and ventilation systems have been in operation since January 1998.

The refurbishing of the SPS smoke detection and ventilation systems uses a new Siemens technology allowing PLCs to communicate directly over TCP/IP, and the new concept of industrial control integration and data distribution proposed by the TDS [7].

The aim of the system is to detect fires in the SPS accelerator and to activate smoke extraction via the tunnel ventilation system according to a predefined plan. The supervision of these safety systems is performed from the Technical Control Room (TCR), Safety Control Room (SCR) and locally from the SPS surface buildings via industrial PCs.

2.5.1 Architecture

The TDS integrates equipment data coming from three different sources: Siemens PLCs monitoring the SPS ventilation and fire detection systems, and the industrial Landis & Gyr Visonik control system of the SPS air conditioning.

The ventilation and fire detection PLC data concentrators communicate via TCP/IP on a public Ethernet segment to an EC. This process converts and integrates PLC specific data frames to the TDS, using an asynchronous data exchange protocol based on TCP/IP.

The Landis & Gyr Visonik control system communicates to the TDS with a dedicated EC.

The TDS interfaces with the EC through TCP/IP sockets in an oriented connection mode (stream mode). The exchanged messages are defined in the Generic TDS Equipment Access Protocol (GTEAP) [5].

The delivery of each EC is under the responsibility of the company providing the local control system.

Equipment data has to be defined on an Oracle reference database (TdrefDB) along with the TDS topology to host this new interface.

The TDS provides equipment data storage in a real time database, alarm delivery to the central alarm server, data logging, automatic sending of command to the equipment, and data delivery to mimic diagrams [7].

Data sent by the ventilation and fire detection systems will automatically trigger commands to the Landys & Gyr Visonik system to alter the ventilation of the tunnels.

Main System Characteristics

- Siemens S5-95-U PLCs to collect data from fire detection units and air conditioning systems,
- Siemens SINEC L2,
- Siemens S5-115-U acting as data concentrator and connected to SPS Ethernet network via a specific TCP/IP card,
- HP servers running the TDS/RTworks process.

2.6 Characteristics

The characteristics of the main systems running in ST environnement are summarized in Figure 8.

3. EVOLUTION

3.1 Interfacing Issues and Network Connection of Industrial Equipment

For many years CERN has adopted TCP/IP as the communication protocol among workstations, servers and front-end computers. Accelerator and Services Controls are fully implemented in the UNIX environment while the front-end computers run a UNIX compatible real-time kernel [9].

This has not been the case for industrial systems until recent years. Industrial systems need their own private network, run their special communication protocol, have their own real-time kernel and operating system, use their dedicated database, and offer their proprietary controls and monitoring (see previous Télémécanique, BBC and L&G systems).

SPS demineralized water control system was the first interconnected system to the central architecture [9]. The local PLCs are connected to the network via a RS-232 link and G64 ECA acting as protocol converter at very low level.

A second integration step is achieved with Safety and PS Cooling System where the connection acts at the higher layer. A HP-UX station running FactoryLink connects the SINEC H1 process related network with the TCP/IP CERN general network.

More recently, with the SPS smoke detection and ventilation system, a third integration step has been introduced. The PLC data concentrators communicate via TCP/IP on the public Ethernet segment to an EC and the TDS. The L&G Visonik system communicates to the TDS with a dedicated EC.

So, data coming from the Siemens controlled equipment and the L&G equipment can be managed in a global system supervised by the standard UMMI.

3.2 Platforms and Supervisors

The first systems (Télémécanique, BBC, L&G) and some of the subsequent Siemens systems were based on proprietary supervisors and communication networks.

The Télémécanique system was operated by a T2000 central computer assembly programme and the two subsequent ones on VMS systems.

The platforms (servers and platforms) have now been standardized with HP-UX.

After the proprietary servers, an initial step was taken with the introduction of FactoryLink (an open system). It was used either as a gateway (between SINEC H1 and the TCP/IP public network) or as a real supervisor (access control systems).

The systems are currently integrated via the TDS [5] (the SPS detection and smoke removal system).

TDS provides data collected from equipment using a standard TCP/IP interface to the high-level control software. It performs real-time data storage and distribution, alarm filtering, data archiving and playback, and command management in a distributed, multi-platform environment. Technical infrastructure data are used by other CERN control rooms and by those responsible for equipment.

In the TCR environment mimic diagrams are managed via DataView and the alarms via CAS (Central Alarm Server).

For purposes relating to the behaviour of local processes that do not interact with the TCR, LabView applications are implemented.

4. FUTURE OBJECTIVES

The policy is to extend the use of industrial systems beyond the technical infrastructure and several systems are currently being examined or in commissioning [6] in the Accelerator sector.

There are two main underlying reasons for this policy:

- the intrinsic advantages of industrial controls (reliability, broad catalogue choice, availability in the Member States, etc.);
- the Organization's **outsourcing** policy. This policy can be implemented only by introducing widely used systems (industrial controls) that are known to industry.

In order to contain development scatter and know-how and to improve equipment management (contract, spare parts), major efforts are being made to **standardize** in the various fields, namely :

- fieldbus (Profibus, Worldfip, CAN) [11],
- PLC (under way),
- use of TCP/IP protocol at upper layer,

- use of TDS (as a federator),
- use of HP-UX platforms.

The efforts being made to integrate and standardize equipment must be matched by an in-depth review of the respective roles of the various CERN services (specialized groups, control and network groups, Control Rooms).

This integration must be **organizational** (definition of the terms of reference of the various services) and **systematic** with an overall review of the control system in terms of its primary function as part of a process that has no independent *raison d'être*.

From the organizational point of view, two functions can be identified:

- **process management** with monitoring, control, modification, adaptation and process parameter optimization functions. This function is the responsibility of the groups in charge of the activity who will implement it in accordance with the methods and traditions of their trade practice.
- round-the-clock (8760 hours per year) **supervision**, information, centralization and co-ordination functions. This role is typical of Control Rooms (TCR, PCR and MCR) and requires only a limited amount of information and controls.

The TCR's main tool is the alarm system.

Rational supervision of the various systems necessitates unified integration and operation at Control Room level.

Similarly, with a view to use common support services (e.g. to avoid a plethora of networks and systems), the SL/CO network should be adopted.

In this context, the adoption of the TDS represents an essential contribution. This system allows the integration of various industrial systems at the lower level and the use of a single supervision service at the upper level.

From the systems point of view, the use of a strict **methodology** at project management level (e.g. GDPM) and software production level (e.g. ESA-PSS05) will broaden the scope for a policy of outsourcing and co-operation between the various groups and divisions [10].

5. SCADA INTEGRATION SYSTEM

In certain professional activities (e.g. electricity, heating and air-conditioning, and cryogenics) there are specific traditions relating to control systems, and several control and supervision systems (SCADA systems) are available on the market.

These systems are very interesting and should not be ruled out at CERN.

Nevertheless, a number of rules must be complied with to allow centralized supervision and availability of data for the other systems.

This minimum integration is possible by adopting the TDS as shown in Figure 6.

6. CONCLUSION

Industrial Control System Integration is now possible and recommended via TCP/IP networks, and at the control room layer via TDS or other methods described in the present paper.

To achieve inter-group collaboration and good outsourcing, methodology had to be adopted (for project management and software).

For each activity clear terms of reference had to be defined for supervision and process management tasks.

7. ACKNOWLEDGEMENTS

Part of this paper is a synthesis of collective work done in ST Division. I should like to thank all those who have taken part in the various studies carried out [1] [7] [8]. Paragraphs 2.2 to 2.5 are taken from the report mentioned in [8].

I should also like to thank the successive SL/CO Group Leaders: P.G. Innocenti and K.H. Kissler, as well as the current Group Leader R. Lauckner, with whom joint work has been undertaken since 1989 with the aim of achieving a better overall synergy between the two sectors.

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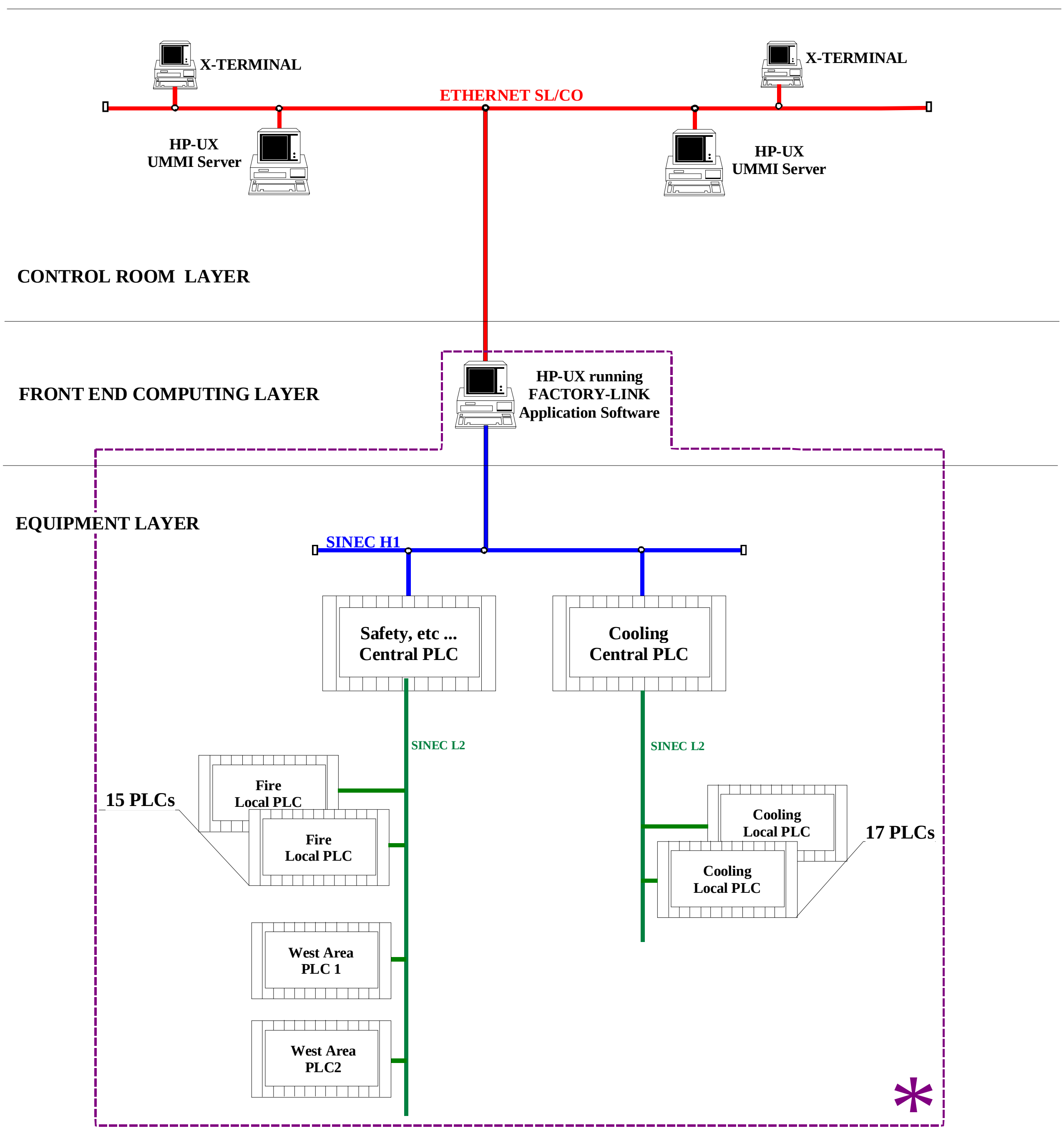


Fig. 1 TCR Industrial Control systems.

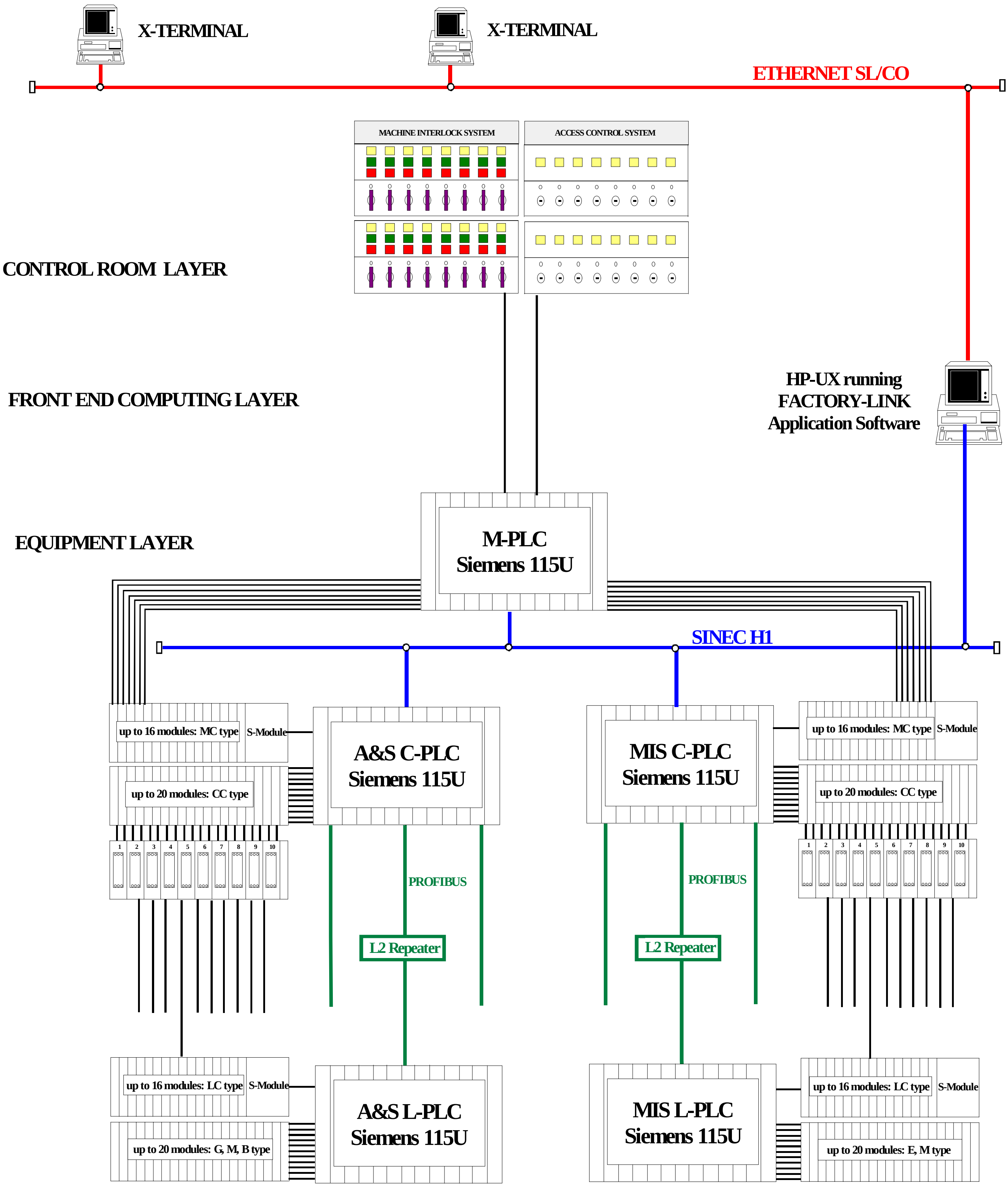


Fig. 2 SPS Access Control.

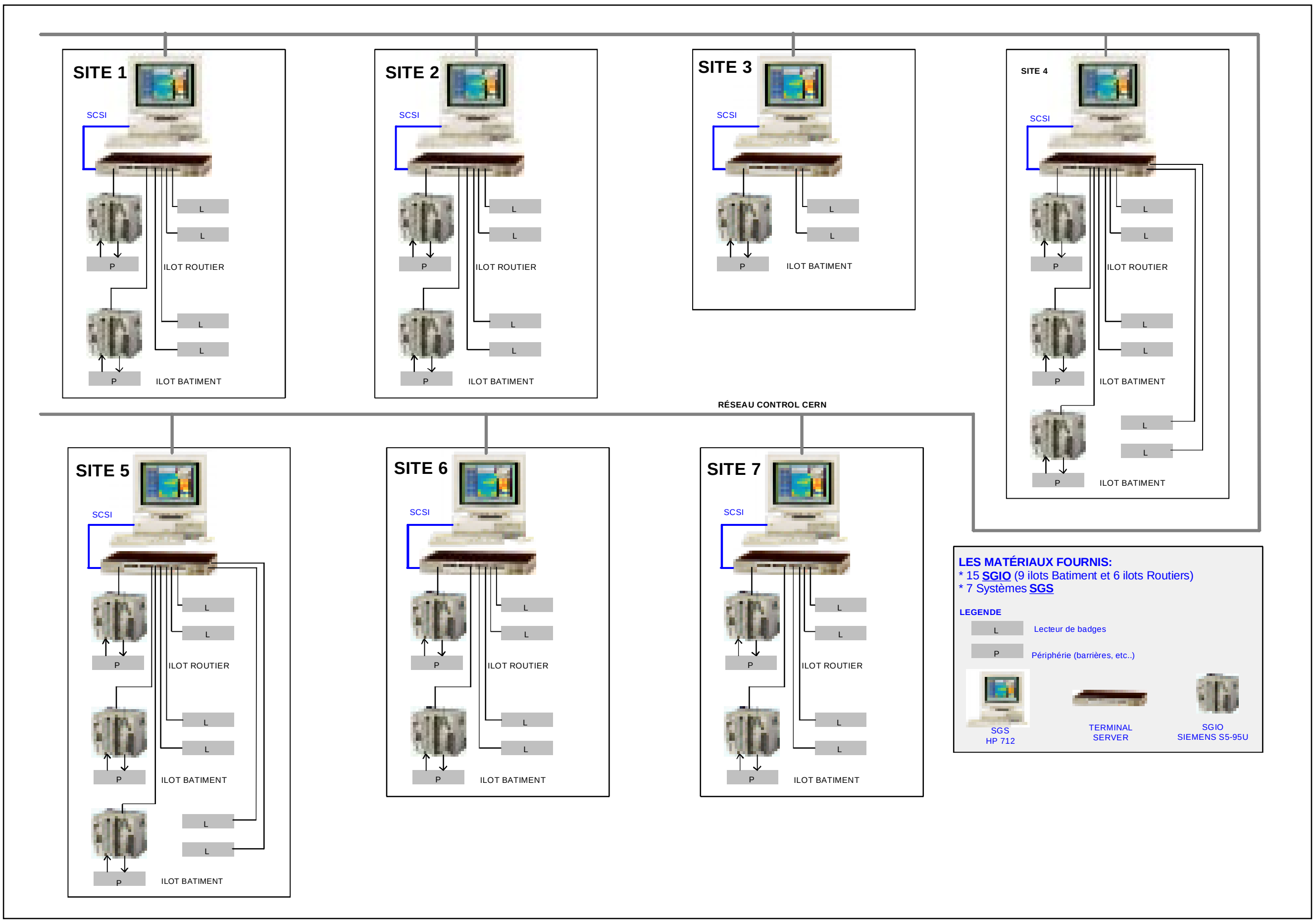
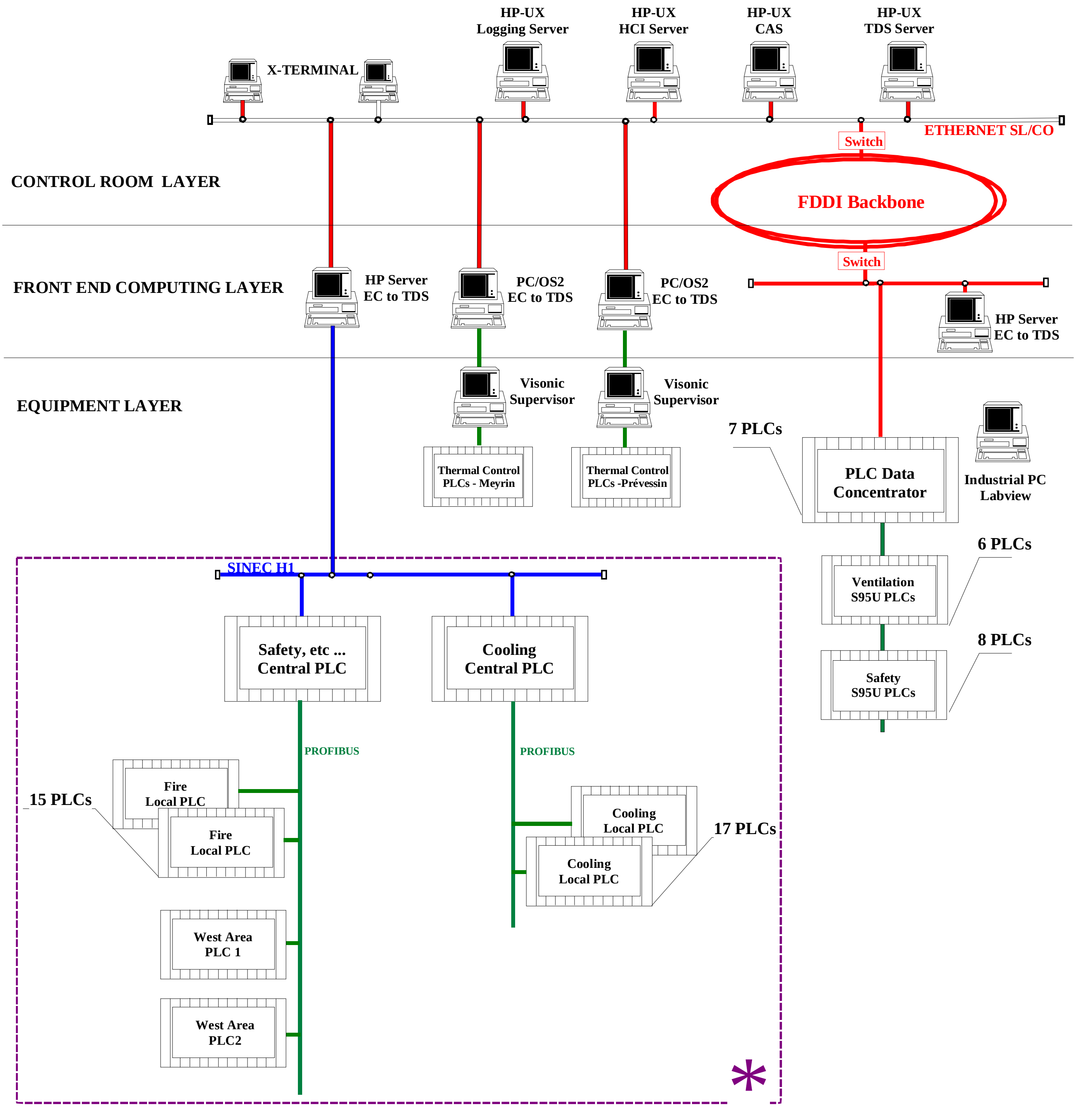


Fig. 3   CERN Sites Access Control.



TCR Industrial Control - Today evolution of fig. 1

Fig. 4 SPS Smoke Detection and Ventilation.

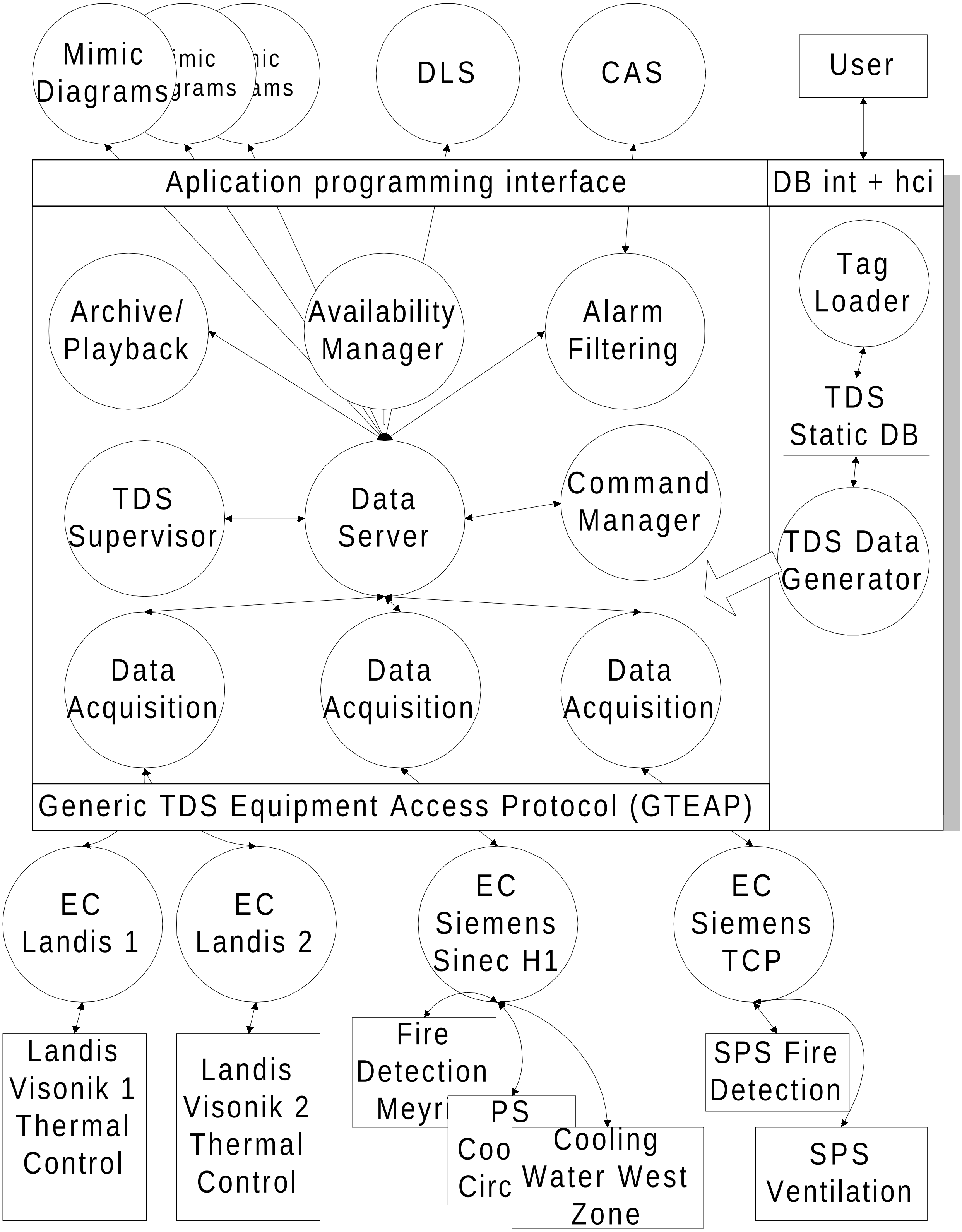
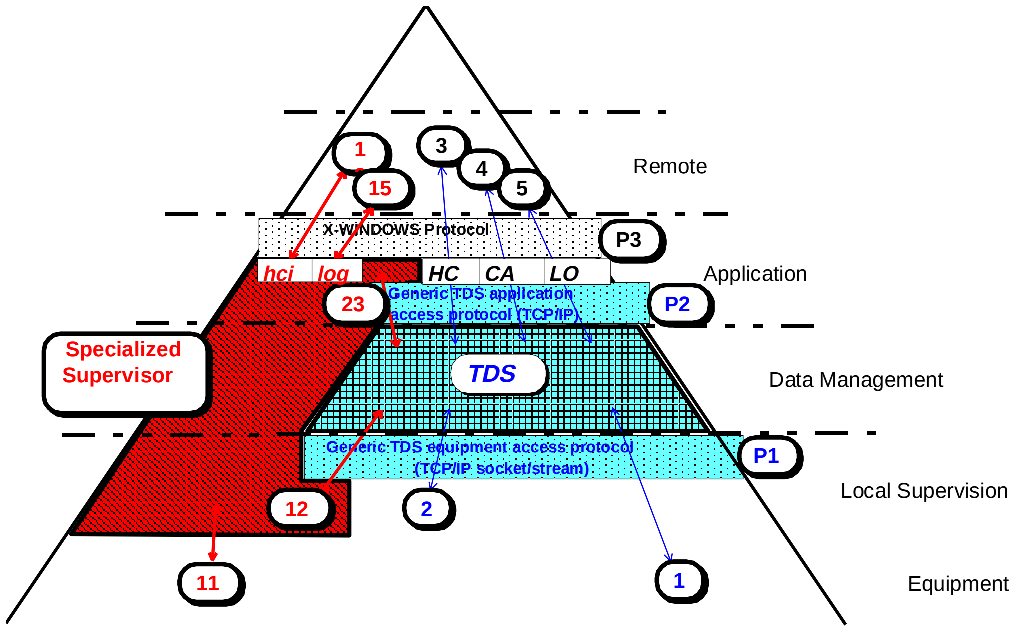


Fig. 5 Technical Data Server.



P1 All equipment-data passing to or from the TDS has to obey the ***Generic TDS equipment access protocol*** [5].

P2 All application-data passing to or from the TDS has to obey the ***Generic TDS application access protocol*** as to specification [5].

P3 All applications are to be distributed according to the ***X-WINDOWS protocol***

1 Direct communication between *TDS* and equipment via e.g. *MICENE*, *ECATCR.*

2 Communication between *TDS* and *Local Supervisor* that is connected to equipment.

3 Standard *TCR* communication between *TDS* and *HCI*, e.g. as for *DV-draw/tools.*

4 Standard *CAS* communication between *TDS* and *Alarm Server.*

5 Standard communication between *TDS* and Data Logging System.

11 *SCADA* communication with equipment, e.g. *SINAUT, VISONIK, SPIDER.*

12 Communication between *TDS* and *SCADA SYTEMS*; **all ALARM and LOGGING data needed for the TCR** have to pass via the TDS to the CAS and the Logging System.

13 All **Synoptic Views** created with a *SCADA SYSTEM* are to be distributable for inclusion in the standard ***TCR Console Manager.***

14 No **Alarm System** proper to the *SCADA SYSTEM* shall be used for the TCR (only ***CAS***).

15 A **Data Logging System** proper to the *SCADA SYSTEM* may be used, provided data displays are distributable for inclusion in the standard ***TCR Console Manager.***

23 Used for all data needed by a *SCADA SYSTEM* from equipment not directly connected to it as in (11), but available through the *TDS;* also used for all actions the SCADA takes on this equipment.

NB a) All monitored information should be defined as *TAGs*, according to to the concept described in [5].

b) In all calls for tenders for a SCADA spanning all functions from *Local Supervisor* over *Data Management* to *Remote Supervisor*, the protocols P1, P2 and P3 are to be specified and the relevant documents to be annexed.

c) In all calls for tenders for LOCAL SUPERVISORS, the protocol P1 is to be specified and the relevant document to be annexed.

d) In all calls for tenders for HCI PACKAGES, the protocols P1 and P2 are to be specified and the relevant documents to be annexed.

Fig. 6 SCADA Integration.

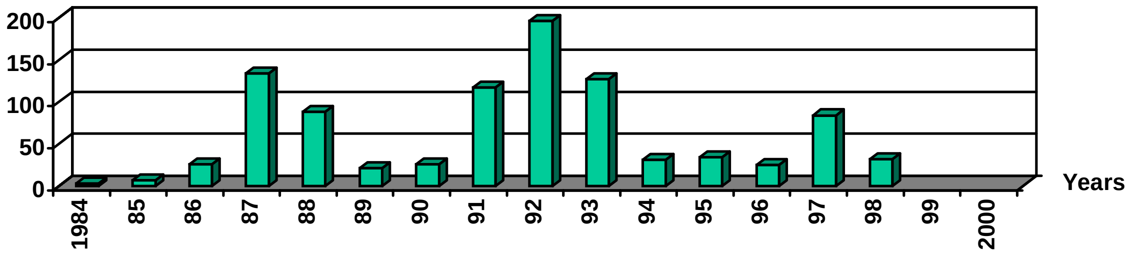


Fig.7 Annual PLC installation at CERN

Systems	**Equipment layer**	**Communication**	**Supervision**
SPS demineralized water	Siemens S5 115-U PLCs interfaced to G64 racks	G64/ MIL 1553 PowerPC/Ethernet	CERN RPC Dataviews HCI
Safety control system	Siemens S5 115-U PLC	L2/ PLC concentrator Sinec H1	FactoryLink Dataviews HCI
West Area cooling water	Siemens S5 115-U PLCs	L2/ PLC concentrator Sinec H1	FactoryLink Dataviews HCI
PS cooling circuits	Siemens S5 115-U PLCs	L2/ PLC concentrator Sinec H1	FactoryLink Dataviews HCI
Computer center cooling	Siemens S5 115-U PLCs	L2/ PLC concentrator Sinec H1	FactoryLink Dataviews HCI
SPS smoke detection and ventilation	Siemens S5 115-U PLCs Industrial PCs	L2/ PLC concentrator TCP/IP	Technical Data Server Labview,Dataviews HCI
SPS access control & Machine interlock	Siemens S5 115-U PLCs Industrial PCs	L2/ PLC concentrator Sinec H1	FactoryLink
CERN site access	Siemens S5 95 U PLCs	L2/ PLC concentrator TCP/IP	TCP/IP Java HCI
PS access control Isolde - East area	Siemens S5 95/115 PLCs	L2/ PLC concentrator Sinec H1	FactoryLink
SPS access control North & West areas	Siemens S5 115-U PLCs	L2/ PLC concentrator Sinec H1	FactoryLink

Fig. 8 Summary Table of some ST Industrial Control Systems.