# A CONTROL SYSTEM FOR THE DESY ACCELERATOR CHAINS

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## *Abstract*

DESY has nine accelerators in operation. The reliable and operator-friendly control of these accelerators is necessary for the successful operation of HERA, DORIS and PETRA in order to provide a good experimental environment for the four experiments at HERA and the numerous users of synchrotron light at DORIS and PETRA. As already reported in PCaPAC'96 PETRA was upgraded to a PC-based control system in spring 1996. Proven concepts and improved programs have been used to renew the control system of storage ring DORIS in the shutdown of 1997. A step by step migration of controls from the old system to the PC-based one is under way and is carried out during normal machine operation of the lepton and proton preaccelerators. In the following an overview of the underlying concepts of the homogeneous control system will be given.


## 1 INTRODUCTION

All of DESY's nine accelerators are operated by a small shift crew from one central control room. The pre-accelerators (see Table 1) LINAC II, PIA and DESY II provide the electrons or positrons for the storage rings DORIS III and PETRA II. LINAC III and DESY III provide protons for PETRA II. PETRA II acts as a pre-accelerator for electrons and positrons for HERA e, of protons for HERA p and as a synchrotron radiation source made up of electrons or positrons.

Table 1: The Preaccelerators

| Accelerator | Type of particle | Max. energy | Length / circum-ference |
|---|---|---|---|
| LINAC II | $e^-/e^+$ | 450 MeV | 70 m |
| LINAC III | p | 50 MeV | 32 m |
| PIA | $e^-/e^+$ (Accumulator) | 450 MeV | 29 m |
| DESY II | $e^-/e^+$ | 8 GeV | 293 m |
| DESY III | p | 7.5 GeV | 317 m |
| PETRA II | $e^-/e^+$ | 12 GeV | 2304 m |
| | p | 40 GeV | |

According to the needs of HERA or DORIS III (see Table 2) the appropriate accelerator chain has to be set up to fill HERA p with protons, HERA e with electrons and DORIS III with positrons. When PETRA II is not needed as preaccelerator for HERA, it is filled with electrons or positrons to produce synchrotron radiation.

Four experiments have been set up at HERA: The ZEUS and H1 experiments study the collisions of the 920 GeV protons of HERA p with the 27 GeV electrons of HERA e in the interaction regions. The HERA-B experiment investigates CP-violation with an internal target in HERA p while the HERMES experiment investigates nucleon spin with polarized electrons of HERA e. PETRA II supports an undulator beamline when operating for synchrotron radiation users. DORIS III services 10 beamlines from wigglers or undulators and 30 from dipoles.

Table 2: Parameters of HERA and DORIS III

| Accelerator | Type of particle | Max. energy | Circum-ference |
|---|---|---|---|
| HERA e | $e^-/e^+$ | 27 GeV | 6336 m |
| HERA p | p | 920 GeV | 6336 m |
| DORIS III | p | 4.5 GeV | 289 m |

Figure 1 below is a schematic summary of the accelerator chains, showing particle flow from their creation in the LINACs through to their destinations DORIS III, PETRA II, HERA e or HERA p.

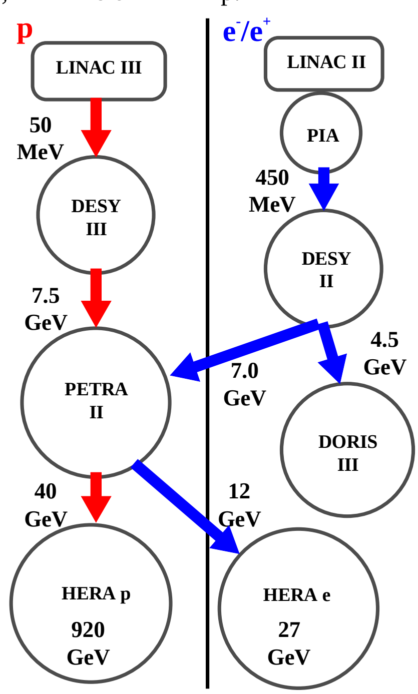



Figure 1: Schematic representation of the accelerator chains.

## 2 CONTROL OF OPERATIONS

Controlling all the accelerators described above involves a lot of devices differing in number and type. The following table gives an idea of what we are dealing with:

Table 3: Main Accelerator Devices

| Device Type | Units (approximately) |
|---|---|
| Main magnet power supplies | 600 |
| Correction coils power supplies | 1400 |
| RF systems | 230 |
| Pulsed magnets power supplies | 70 |
| Vacuum | 3000 |
| Beam position monitors | 800 |
| General beam measurement instrumentation | 300 |
| Air conditioning, water cooling | 500 |

Most of these devices are interfaced to the PCs by means of the inhouse field bus SEDAC[1] [1][2]. A bus is connected to a PC via the standard parallel port using the SEDPC-Controller [3], this assembly is called a SEDAC-Line. In total there are some 140 lines connecting 1100 crates, each crate housing up to 11 interface modules.

About 300 PCs control these devices. Information is made available to the operators in the central control room on about seventy 20" color monitors. Sitting at the PCs in the control room the operators can actively control the above-named devices and are therefore at all times able to supervise the accelerator chains. Software programs are constantly being (re-)developed in order to ensure optimal functioning of the whole process.

## 3 CONTROL SYSTEM SEGMENTS

Closing all the accelerators down at any one time is unthinkable. This is one reason why it is impossible to build a single unsegmented control system for all the accelerators. Following good engineering practice the control system is split into control system segments:

Table 4: Control System Segments

| Name | Accelerators controlled | Number of PCs |
|---|---|---|
| IpLan | LINAC III, DESY III | 30 |
| IeLan | LINAC II, PIA, DESY II | 35 |
| DoLan | DORIS III and beam-lines | 40 |
| PeLan | PETRA II and beamlines | 50 |
| HeLan | HERA e and beamlines | 45 |
| TINE | HERA p | 100 |

These segments are formed according to the following criteria:

- minimum interference between segments
- minimum data exchange
- between 10 and 50 PCs in one segment
- PCs of one segment are connected via 10Mbit/s thin ethernet technology without a router, building a LAN[2].
- actual device information available in the LAN
- intersegment network communication available
- autonomous operation of a segment
- similar configuration and design

HERA p obeys other criteria but can be seen in this context as a segment. There are contributions about its system TINE [4] in this workshop.

## 4 DESIGN OF CONTROL SYSTEM SEGMENTS

There are some building blocks which we use in all segments. The PCs in their different roles are one building block. With the exception of the File Servers they run MS Windows 3.11, the programs are written in Visual Basic 3. The File Servers run Novell Netware 4.11. We distinguish four kinds of PCs:

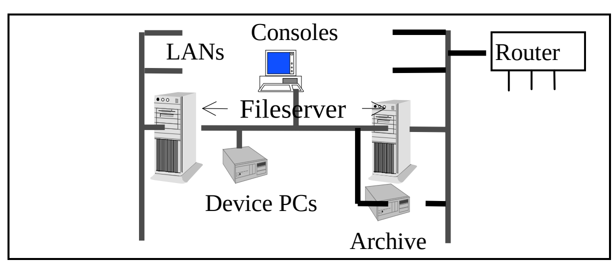
- Device Servers with access to the interface modules, mainly SEDAC.
- Console Servers for the operator interface
- LAN Servers for common facilities in a LAN
- File Servers

Standardized program packages for common tasks in all segments are another building block. Device access via SEDAC and the network communication are other important blocks.

The LINAC III control system as an example of how the building blocks have been used is described in a paper in these proceedings [5].

Figure 2: Schematic view of a Control System Segment

### *4.1 Device Server*




One Device Server is employed for each device type of an accelerator. There are normally at least 3 programs running on a Device Server:

- an update program reading the present status of the devices and sending them as broadcast packets into the LAN.

[1] Serial Data Acquisition and Control system

[2] Local Area Network

- a command execution program connected to a console program
- a program servicing the File Operator program running at the console.

### 4.2 Console Server

Console Server PCs display the status of the devices by simply ‘tuning’ their packet filter to the identification of broadcast packets they are interested in. Additional display programs add no extra load to the network or Device Servers.

A lot of devices are controlled by the standard Device Manager Program [6] which allows the devices to operate in all their functions. Simultaneous operations on several devices - spread over many Device Servers - is done with the File Operator Program [7]. To some extent the consoles are automatically configured according to the operation mode of the accelerator. The operator will always find the same information at the same place.

### 4.3 LAN Server

The Radio PC generates the ‘cycle message’[8] for the LAN. This broadcast packet contains general accelerator parameters. It is send every second and there is one for each accelerator in the segment. The Device Servers listen to the ‘cycle message’ and start their update programs on reception.

One ALARM Server [9] handles error- and alarm-messages generated by the Device Servers or the ALARM PC itself.

The Archive Server(s) collect and retrieve selected data out of the broadcast packets of the Device Servers.

### 4.4 File Server

The File Servers act as a filestore and as a router. Each segment has two File Servers, the Control File Server and an Auxiliary File Server. The Control File Server is the repository of all programs (including the operating system for the PCs) as well as all data to operate the accelerators. The Auxiliary File Server stores files which are not essential for the operation; but they are meant for trouble shooting, offline analysis of runs etc.

The routing capabilities provide connectivity to other segments but prohibit broadcasts to be flooded into all other segments.

Although a segment can operate autonomously, i.e. disconnected from the other segments, the File Servers of all LANs as well as all other network resources are objects of one common NDS[3] Database.

### 4.5 Standardized Program Packages

The Device Manager and the File Operator programs have been already mentioned above.

[3] Netware Directory Services © Novell

For some device types there are programs which are very similar in all segments. Examples are the vacuum devices and magnet power supplies. The vacuum example is presented in these proceedings [10].

The number of programs in one segment to operate the accelerators is between some 100 and 300.

### 4.6 Network Communication

Network access is provided by inhouse developments of custom controls which add peer to peer datagram- and connection oriented communication functionality to the Visual Basic 3 language. These controls allow usage of Novell’s IPX- as well as the TCP/IP protocol.

IPX broadcasts play an important role. All status information of all devices is available to all PCs in the LAN with an update rate of 1Hz by this means. Because all Device Servers start their update cycle triggered by the ‘cycle message’ the LAN usage does not vary much from second to second and may be called the ‘fingerprint’ of the LAN.

The normal load is slightly less the worst case load. Average utilisation varies over the LANs from 7% to 25%, nearly half of this is contributed by broadcasts.

Some information is useful and desired in other LANs, Device Servers then send multiple packets with different destination LAN addresses.

## 5 GLOBAL TASKS

Some tasks are independent of an accelerator or common to all accelerators. PCs serving these tasks are located in the LANs connecting the Control File Servers or the Auxiliary File Servers.

These tasks are:

- Synchronize all Radio Servers in the LANs by one Main Radio.
- Provide Operator Consoles to operate vacuum devices, magnet power supplies of all accelerators as well as to control the access of persons into the accelerators.
- Give access to the DESY Intranet and to TINE control system segment
- Supply the data of the Archive Servers and the Auxiliary File Servers for a Web Server to publish them for further analysis.

## 6 TIME SCALE AND STATUS

We started with the PC project in 1994 with a learning phase. At that days the control system was based on about 60 NORD[4]-minicomputers. Today we still have 10 running in mission critical jobs, which we will have removed at the end of this year.

[4] Computers of NORSK DATA company, Norway, ceased to exist.

The milestones of our control system project are listed in the table below:

Table 5: Milestones in Control System Project

| Year | Milestone |
|---|---|
| 1994 | Development phase<br>Start of PC project, |
| 1996 | Development and installation phase<br>PETRA upgraded to PC-based Control System Segment<br>Part of HERA e Control System Segment realized |
| 1997 | Development, installation and operation phase<br>DORIS II upgraded |
| 1998 | LINAC III upgraded<br>parts of LINAC II, PIA, DESY II, DESY III upgraded<br>HERA e upgrade finished<br>HERA p (TINE) completed |
| 1999 | End of era of NORD-minicomputers.. |

## 7 CONCLUSION

In the last five years our experience with the three phases - development, installation and operation - of our new control system project allows us to draw the following conclusions:

- The commercial standard PCs of the 95 vintage or later are powerful and reliable enough for professional use in a larger computer network designed to control accelerators of different sizes and complexities.
- Integration of new hardware into a running control system is possible without major problems.
- The available commercial software tools are spectacularly powerful at an extremely low price
- Upgrading inhouse developed applications to the latest operating system environment was possible without undue effort.
- Given the wide-spread use of PCs one can assume knowledge of the basics and only specialist explanations are required.
- One major disadvantage of the new software tools arises from their immense variety of possibilities they offer. The art of writing a suitable program for accelerator control is to use as little as possible of what is offered by the software - without using too little.
- The concept described allowed a smooth upgrading from the NORD computer controlled system to the PC based one in a period of approximately six years. It was not even a replacement, but a redesign adding a lot of new features we could not even dream about in the NORD era.
- A great uniformity has been achieved, this eases the job of the operators when switching from one accelerator to another and of course the developers job too.

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