

OVERVIEW OF THE PERSONNEL SAFETY SYSTEM AT THE HEIDELBERG ION THERAPY FACILITY

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Abstract

The HIT (Heidelberg Ion Beam Therapy) Centre is the first hospital based heavy ion therapy facility in Europe. It is operated by a newly founded daughter of the university hospital of Heidelberg, the HIT GmbH. In accordance with the German radiological protection ordinance, a personnel safety system (PSS) was installed during the commissioning of the accelerator. Main functions of the PSS are radiation protection, gate control, emergency stop handling, change of the state of the protection areas and safety interlocks. The PSS is a stand alone part of the accelerator control system and consists of several OPC servers and a special designed GUI for the control room. The installation of the PSS was started in June 2006 and finished in March 2008. This presentation will report on the concept and realization of the PSS.

INTRODUCTION

The accelerator at the HIT Centre [1] consists of two 14.5 GHz electron cyclotron resonance (ECR) ion sources, a low energy beam transport system (LEBT), a 7 MeV/u linear accelerator (LINAC) and a compact synchrotron with a circumference of 65 m ($B\rho=6.5$ Tm). After extraction, the beam is distributed by the high energy beam transport (HEBT) to the two horizontal treatment rooms and a heavy ion gantry for 360° patient irradiation. In addition a quality assurance and experimental room is available. Due to the architecture of the accelerator area the PSS has to observe nine restricted access areas (SB1-SB9) (Fig.1).

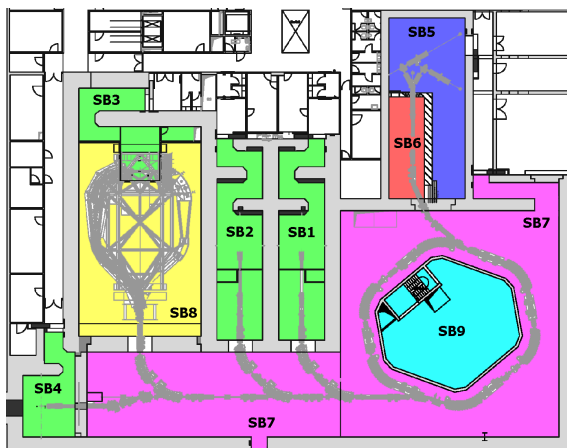


Figure 1: Location of SB1-9 in the accelerator area.

According to the German radiological protection ordinance [2] all these areas are defined as radiation protection areas in the following way:

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- the treatment rooms SB1-3 and the quality assurance and experiment room SB4
- the ion source room SB5 and the linac and synchrotron rooms SB6+7
- the gantry room SB8 and the storage room within and under the synchrotron SB9

Due to the installation dimension (15m×15m×25m) of the gantry, the area SB8 is a multi-storey room, ranging from the basement to the first floor. The area SB9 also includes the interior zone of the synchrotron with the cooling system. During accelerator operation only the ion source room is partly accessible for the personnel at all times. The other restricted access areas are inaccessible during the transmission of the beam from the ion source to a treatment room.

DESIGN GOALS

Design and implementation of the PSS has been carried out in collaboration with GSI (Darmstadt) and EAG company (Wiesbaden)[3]. All components must fulfill the European standard EN 954-1 (hardware) and IEC/EN 61508 (software).

The following design goals had to be fulfilled:

- only registered persons can enter the accelerator and treatment rooms (administration system)
- all status information is available for the accelerator control system
- a local status display shows all pertinent information independently from the accelerator control system
- the PSS must be in a secure state in case of any error
- the interlock system must be designed as a redundant and diverse system
- a radiation monitoring system must be integrated

OVERALL ARCHITECTURE

Hardware Architecture

The PSS hardware is implemented using a rack containing the safety control, the electrical power supply Control Hardware and Low-Level Software

and the I/O interface unit. The control unit is a safety-programmable logic controller (PLC) of the Hima "HiMatrix" series. Decentralized peripherals are connected via a safe Ethernet bus. Data transmission occurs at 100 MBit/s. This part of the PSS includes all safety relevant functions whereas the non safety relevant functions are implemented in software. The central Rack (Fig.2) contains:

- 1 Hima safety PLC F60
- 3 decentralized digital I/O modules DI16/DO16
- 9 decentralized digital relays output modules R-DO8
- Strip terminal for all I/O signals

All in all we have a need for 306 channels, 151 sensors and 155 actuators. All mounted components can be replaced easily and fast in case of damage. The PLC continuously performs self-tests and places the accelerator in a state of alert whenever a failure is detected. The rack contains a closed system with neither operational controls nor diagnostic components. In addition, there exist some subsystems which are independent of the PSS. For access control to all restricted accelerator rooms a commercial system by Primion is used. This system is connected to the PSS via potential-free wire. Furthermore the power supply to the accelerator is shut off if one of the panic buttons of the emergency shutdown subsystem is pushed. A radiation monitoring subsystem consisting of several dose rate monitors (Berthold Technologies, LB111 gamma and neutron monitor) is mounted in the accelerator area. This system provides alert signals to the PSS by means of two potential-free connections causing a beam shut-off in the corresponding area. In addition the air control system i.e. air supply as well as air exhaust is monitored. The Primion access control system consists of a central password protected database, in which the access authorizations for all employees are stored. Each employee has a personal RFID-card which is used to control admission to restricted area by means of a card reader at the door. This reader sends an enabling signal to the PSS over a hardware contact. The PSS status for each radiation protection area has to be available on a local status display. Especially the state of the treatment rooms must always be visible on a local panel. This display is mounted at the entrance doors to all areas (Fig.2). In the upper part of the panel a radiation warning sign (trefoil) is mounted. The state of the area is displayed by turning on the corresponding LED in the middle of the panel. The card reader of the access control system is mounted at each door and allows a fast identification via a touchless RFID-card sensor. Furthermore an emergency button and the manual controls of the shielding doors are placed in the lower left part of the control panel. It is impossible to change the state of the radiation protection area solely at the local control panel. Only authorized users can switch the state on an accelerator control system (ACS) [4] client PC running the PSS GUI.

Classical Topics



Figure 2: Layout of the central PSS rack (left) and the display at the shielding doors (right).

PSS LOGIC

States of the Radiation Protection Areas

Each radiation protection area can be in exactly one of several defined states. These states are communicated to the ACS which need this information as one of the preconditions for beam operation. The radiation protection areas can be in one of the following states with regard to the PSS:

Area accessible In this state a radiation protection area is freely accessible to staff. The respective radiation protection door can be opened or closed without restrictions.

Sweep In this state the radiation protection area is searched for any persons in the area, before the state can be changed into "area closed". The sweep procedure is completed by pushing a series of search buttons in a specific sequence.

Controlled access This state is planned for use in specific radiation protection areas of the accelerator. In this state a controlled access and departure of persons is possible. With the help of lattice doors entering and departing persons are registered and counted. To change into the state "area closed" no renewed sweep procedure is necessary if person counter is equal to zero.

Area closed Only in this state beam operation in this area is possible (exception: ion source room SB5). The ion source room is freely accessible because the X-rays caused by the operation of the ion sources are shielded by means of lead screenings around the sources. For the treatment rooms (SB1-3) this state is divided further into therapy operation and experiment operation.

Alarm In this state a safety device has been activated, or an undefined response was detected. In this case no beam operation including this area is possible.

Control Hardware and Low-Level Software

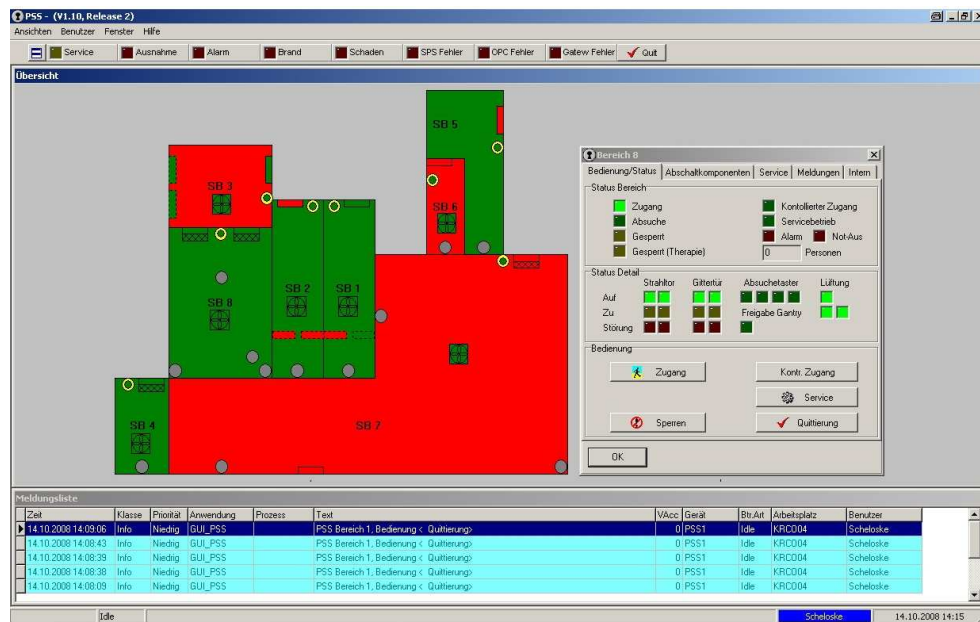


Figure 3: GUI PSS with location of various PSS components in the accelerator area.

Software

The non safety relevant functions are implemented in software. The state machines controlling the area states are implemented as software modules in the PLC. The PLC monitors every radiation protection area in itself, however mutual dependencies on states are taken into consideration. Each state of the radiation protection area described above is correspondent to a state machine. The PLC is connected via Ethernet to an OPC server and through this to an ACS client PC running the PSS GUI.

Monitoring of PSS Status

The PSS is controlled by a graphical user interface (GUI) on an ACS client (Fig.3).

The GUI is comprised of three major sections: The top section visualizes all possible error states of the PLC. Possible errors are fire alarm, gateway error, self-detected error of the PLC or I/O card error. The middle section contains all information about the individual radiation protection areas. In a subwindow the area state can be changed and detail information of the area is displayed. An area is displayed with a green background when accessible and with a red background when closed. Additionally the conditions of the most important sensors are shown in the GUI. The shielding doors are symbolized as green (opened) or red (closed) rectangles. The dotted rectangles symbolize lattice doors or normal doors without any shielding. The ventilation monitoring (displayed as a green propeller) turns from green to red if an error occurs. The panic buttons are pictured as green circles with yellow borders. When a panic button is pushed, the green center turns into red and an area alarm is triggered. In case of any alarm the whole area flashes red to attract attention to the error. The grey circles

symbolize the sweep buttons, which must be pushed in a specific sequence to lock the area. The bottom section contains a message list, where all changes and actions in the PSS are documented including a time stamp and the user name.

CONCLUSIONS

The operation of an ion therapy facility requires a highly reliable personnel safety system to minimize any failure and to assure best possible safety for employees and patients. Due to these requirements a common-standard I/O system with a programmable PLC was implemented. This system is reliable and safe in case of any failure. No additional external support is needed, changes in the system or integration of further components are easily possible. The graphical user interface permits a fast and easy overview of the safety status of the accelerator facility. The PSS is a high-performance safety system which runs very stable and with a failure rate of less than 1% since the end of the commissioning.

REFERENCES

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