THE NEW PLC BASED RADIATION SAFETY INTERLOCK SYSTEM AT S-DALINAC*

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Abstract

The Superconducting-DArmstadt LINear ACcelerator (S-DALINAC) is a recirculating electron accelerator with a maximum design energy of 130 MeV operating in cw mode at a resonance frequency of 3 GHz at the university of Darmstadt since 1991 [1]. Polarized [2] or unpolarized electron beams can be accelerated and used as a probe for nuclear and astrophysical experiments.

This paper will report on the new PLC (Programmable Logic Controller) based radiation safety interlock system at S-DALINAC installed recently to replace the outdated and not expandable existing, hardware-based system.

The new interlock structure consists of a personnel interlock as well as a machine safety interlock. Both subsystems shut down the radio-frequency (RF) of the superconducting cavities and the high voltage of the chosen electron source if one of the necessary conditions of the interlock system for the actual operation mode of the S-DALINAC is broken.

INTRODUCTION

From the point of view of the radiation safety interlock system the S-DALINAC consists of two electron sources, superconducting RF cavities, an injector linac, a main linac, two recirculation beam lines, a nuclear resonance fluorescence (NRF) experimental place as well as three high energy experiments in the experimental area. Due to the different operation modes of the accelerator the personnel interlock system is based on three levels permitting an optimized combination between locked areas for safety reasons and the possibility to work in other areas at the same time. Elements like light barriers, light grids and a specially defined searching process increase the safety of the system and make it user-optimized. All areas which might be locked during operation of the accelerator have a high amount of emergency shutdown buttons.

The machine safety interlock prohibits the S-DALINAC beam transport and vacuum elements from being damaged due to malfunctioning of any components during accelerator operation. One part of the machine safety installation is the valve controls with an overview about the complete vacuum system of the S-DALINAC. Thereby the operator is able to get an overview and to spot malfunctioning of any vacuum pumps quickly. The additional monitoring of all dipole power supplies prevents damage of the beam line in case of a failure of a power supply which would cause the beam to be dumped accidentally.

PERSONNEL INTERLOCK SUBSYSTEM

To prevent the staff from entering areas with a high dose rate accidentally a personnel radiation safety interlock system was installed. A three-level structure reflects the different operation modes and provides the possibility of working on some experimental infrastructure during distinct operation modes.

The Three Level Structure

In level one the required interlock conditions for either operating just the RF of the superconducting cavities or additionally one of the electron-guns to provide an electron beam for NRF experiments [3] are controlled. Furthermore the power supply of the dipol magnets bending the electron beam into the main linac is demanded to be switched off. The distribution of the resulting radiation protection area is shown in fig. 1(a)

The second level is mainly used for the optimization of the beam, e.g. for setting up a recirculating beam in the non-isochronous scheme [4]. The main linac as well as the recirculation beam lines are in operation then. At the same time the experimental set-ups in the experimental hall can be prepared. For the second level the exclusion areas enlarge as well as a new controlled area occurs, see fig. 1(b). To ensure that the beam is dumped safely instead of going into the experimental area the power supplies of the two dipole magnets guiding the beam from the accelerator hall into the experimental area are demanded to be switched of by the personnel interlock system.

After preparation of the beam for the high energy experiments [5–7] the personnel interlock system has to be switched to level three. In this level all areas are declared to exclusion ones, see fig. 1(c).

Elements of the Interlock System

The most important elements are the emergency shutdown buttons for the RF and the beam. 33 of them are installed in all potential exclusion areas and one in the control room. All of them are hardwired. Figure 2 shows a typical box including the emergency shutdown button, an always glowing light for orientation to the box and a searching light. The searching light is flashing or glowing during the searching process. In the flashing case the box needs to be confirmed, in the glowing one the box has been approved.

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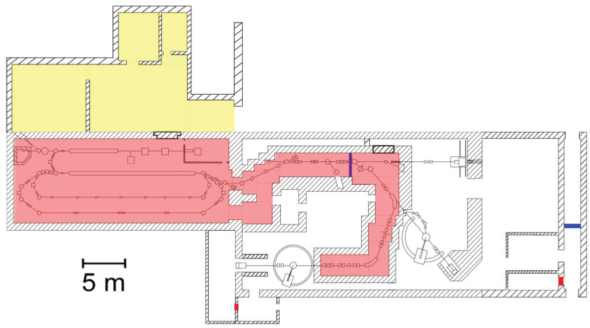
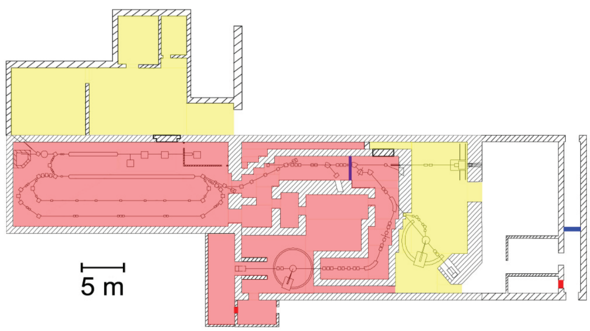
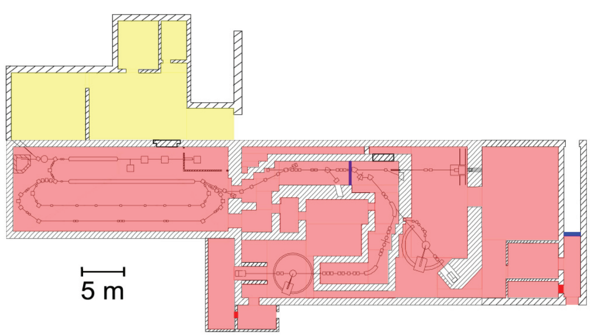


(a) The radiation protection areas for level one.



(b) The radiation protection areas for level two.



(c) The radiation protection areas for level three.

Figure 1: Overview about the radiation protection areas for all three levels. Yellow defines a controlled area, red an exclusion area. The blue boxes indicate permanently installed grids, the red ones permanently locked doors.

The light grid and the light barrier, see fig. 3, work together to help during the searching process of an area which will be locked soon. These elements enable the option that only one person can search the corresponding room.

During the searching process the light grid observes the main doors of complex areas together with the light barrier. If someone enters the area while it is searched the signal-horn sounds and the searching process is aborted. The combination of light grid and light barrier ensures that the person who searched the room can leave it without aborting the process.

Figure 2: The box including the emergency shutdown bottom as well as a searching light and an always glowing light for orientation in the dark.

MACHINE SAFETY INTERLOCK SUBSYSTEM

Each beam operation mode has machine safety conditions in addition to the personnel interlock system level. These conditions are composed of open or closed valves and the power status of dipole power supplies.

If a beam mode was chosen the operator knows which machine safety interlock conditions need to be fulfilled. After meeting these points as well as the corresponding personnel interlock conditions the high voltage of the electron source can be switched on.

THE USER INTERFACE

Two touchscreens are used to observe the status and to operate the interlock system.

Figure 4 shows the operation overview. The operator can choose between both electron sources and decide about the beam mode. After choosing these two options all conditions in the same column need to be fulfilled. The main part of these conditions belong to the personnel safety interlock subsystem, all other points to the machine safety interlock subsystem. This screen sums up all minor conditions which are collected in a superior name.

To identify which minor conditions belong to which superior condition the operator can use the screen shown in fig. 5 in the case of the personnel safety system. It has an overview of all three levels with every single existing condition, mainly the status of the emergency shutdown buttons and the status of the different doors.

SUMMARY

This paper reported on the new installed PLC based interlock system at S-DALINAC, which replaced the former hardware based installation.

It consists of two subsystems, a personnel interlock and a machine safety interlock part. The personnel interlock is based on a three level scheme. It works with a network of hardwired emergency shutdown buttons in all potential exclusion areas as well as one in the control room. Locking

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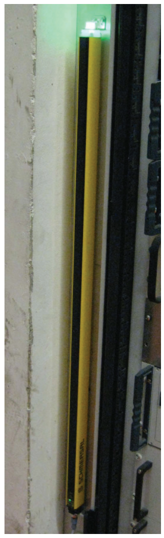
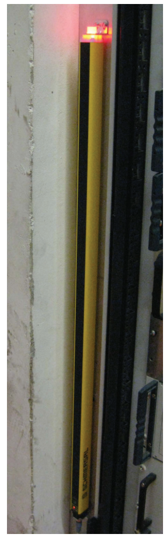
(a) The emitter of the light grid system.



(b) The acceptor of the light grid has a green light to show that nobody was detected by the system.



(c) The red light of the acceptor shows that someone has interrupted the signal.

(d) The combined emitter and acceptor element of the light barrier.

(e) The reflector mirrors the signal coming from the emitter back to the acceptor.

Figure 3: A light grid (see fig.3(a), 3(b) and 3(c)) consists of an emitter and an acceptor. The combination of these two show if someone is crossing the light grid. The light barrier consists of a combined emitter and acceptor element (see fig. 3(d)) and a reflector (see fig. 3(e)) for mirroring the signal. Both systems work together to detect if someone enters an area while it is searched and allow the person who searched it to leave the area without aborting the process.

an exclusion area requires a special searching process. Elements like light barriers and light grids make the searching process feasible for only one person and increase the safety of the system, too.

The machine safety interlock subsystem completes the new installation. It prevents damage from the accelerator due to malfunction of dipole power supplies or vacuum problems.

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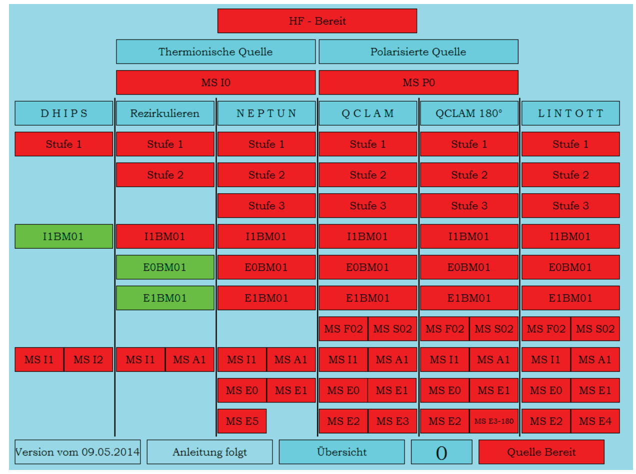

Figure 4: On this screen the operator can choose the electron source as well as the beam mode. The corresponding column shows the superior conditions which need to be fulfilled for the operation.

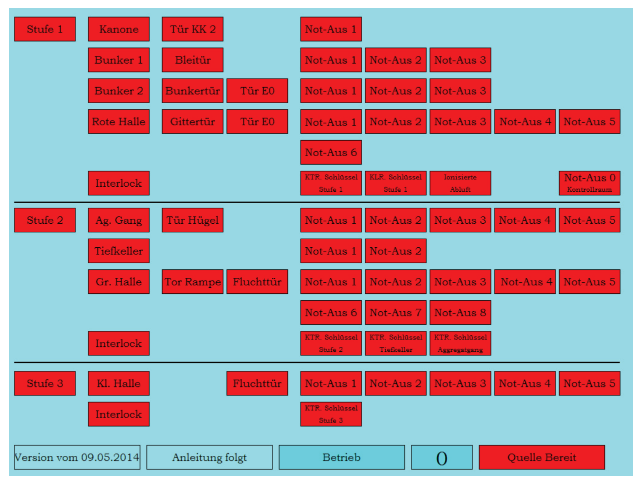

Figure 5: This screen shows the three levels of the personnel interlock subsystem with their conditions, mainly the status of emergency shutdown buttons and doors.

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