MACHINE PROTECTION SYSTEM FOR THE SPIRAL2 FACILITY

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Abstract

The phase 1 of the SPIRAL2 facility, the extension project of the GANIL laboratory, is under construction in Caen, France. The accelerator is based on a linear solution, mainly composed of a normal conducting RFQ and a superconducting linac.

One of its specificities is to be designed to accelerate high power deuteron and heavy ion beams from 40 to 200kW, and medium intensity heavy ion beams as well to a few kW. A Machine Protection System has been studied to control and protect the accelerator from thermal damages for a very large range of beam intensities and powers.

This paper presents the technical solutions chosen for this system which is based on two technical subsystems: one dedicated to thermal protection which requires a first PLC associated with a fast electronic system and a second dedicated to enlarged protection which is based on a safety products.

INTRODUCTION

The SPIRAL2 facility under construction at Ganil will extend the possibilities for experimental nuclear physics towards more exotic beams [1].

After being pre accelerated by a RFQ, the primary stable beams (deuterons, protons, light and heavy ions) accelerated by the Linac will range from a few 10 µA to 5 mA in intensities, and from 0,75 A.MeV up to 14,5A.MeV for heavy ions, 20 A.MeV for deuterons and 33 MeV for protons in energies. Moreover, beam time structure may also vary from continuous beams (88 MHz) to chopped beams (1Hz to 1kHz) and single bunch mode beams.

The Machine Protection System [2] has thus to be designed to monitor a very large beam power range and various types of beam time structures.

MAIN FUNCTIONS OF THE MACHINE PROTECTION SYSTEM

The main functions of the SPIRAL2 Machine Protection System (MPS) are the followings:

- Protect the beam tubes and insertion devices (slits, faraday cups, targets,…) from beam thermal damages,
- Control the operating range of the facility,
- Control the accelerator device activation due to beam losses (beam losses limited to 1W/m for D^+ beams),
- Ensure a reinforced protection of the beam dumps and targets, which all have their own protection system.
- Ensure a safety class protection of the safety class fast vacuum valves.

RESPONSE TIMES

Thermal calculations have been performed in order to:

- Evaluate the response time necessary in case of instantaneous high beam losses,
- Calculate the thresholds under which permanent beam losses are acceptable.

Response Times for the Thermal Protection

The response times are calculated according to the various material temperature increases due to beam losses. Furthermore, the operation temperatures must remain much below the fusion temperature, in order not to degrade the material characteristics (usually, the thermal stress limit is considered [3]).

A maximum of 50µs response time is calculated for aluminum chambers, while a maximum of 35µs response time is obtained for stainless steel chambers, for which a limit operation temperature of 1000°C is considered [4].

Response Times for the Reinforced Protection of Beam Dumps and Targets

The response time is determined by the thermal resistance of the target that receives the ion beams. The MPS must cut the beam in time to preserve the experiment target in case of dysfunction of the thermal MPS controls. This time is estimated at about few ms taking into account a safety margin. Several cases have been considered:

- a stop of the rotation of the target,
- an error in sending the beam intensity higher than the capacity of the target. In this case the control system has to cut the beam intensity within the specified time.

Response Time for the Safety Class Fast Vacuum Valve Protection

The response time is determined by the time of moving the valve when the system is triggered. This time depends on the type and the size of the valve. Time to set in motion the smaller valve (DN40) is 2 ms and the closing time is 8 ms. So the reaction time should not exceed 2 ms.

Response Times to Cut the Beam

The two actuators which cut the beam are the chopper for thermal fast protection cuts and the RFQ for the safety class beam cut. The RFQ was chosen for the safety class beam cut because it is simpler and safer than the chopper.

ARCHITECTURE OF THE MACHINE PROTECTION SYSTEM

The SPIRAL2 Machine Protection System is based on three technical subsystems, as presented in Fig. 1:

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- One dedicated to thermal protection, which requires a fast electronic protection system (a few tens of µs) and a PLC (10 ms range).
- One dedicated to enlarged protection, based on robust technologies consisting of a PLC associated with a redundant hard wired system. It controls the operation domain of the facility from the safety point of view for losses, beam intensities and the integrity of the various beam dumps and targets, among which actinide targets.
- One dedicated to protect the safety class fast vacuum valves of the facility. It's a specific device because this system is safety classed. The safety class fast vacuum system has a central protection system from the safety point of view.

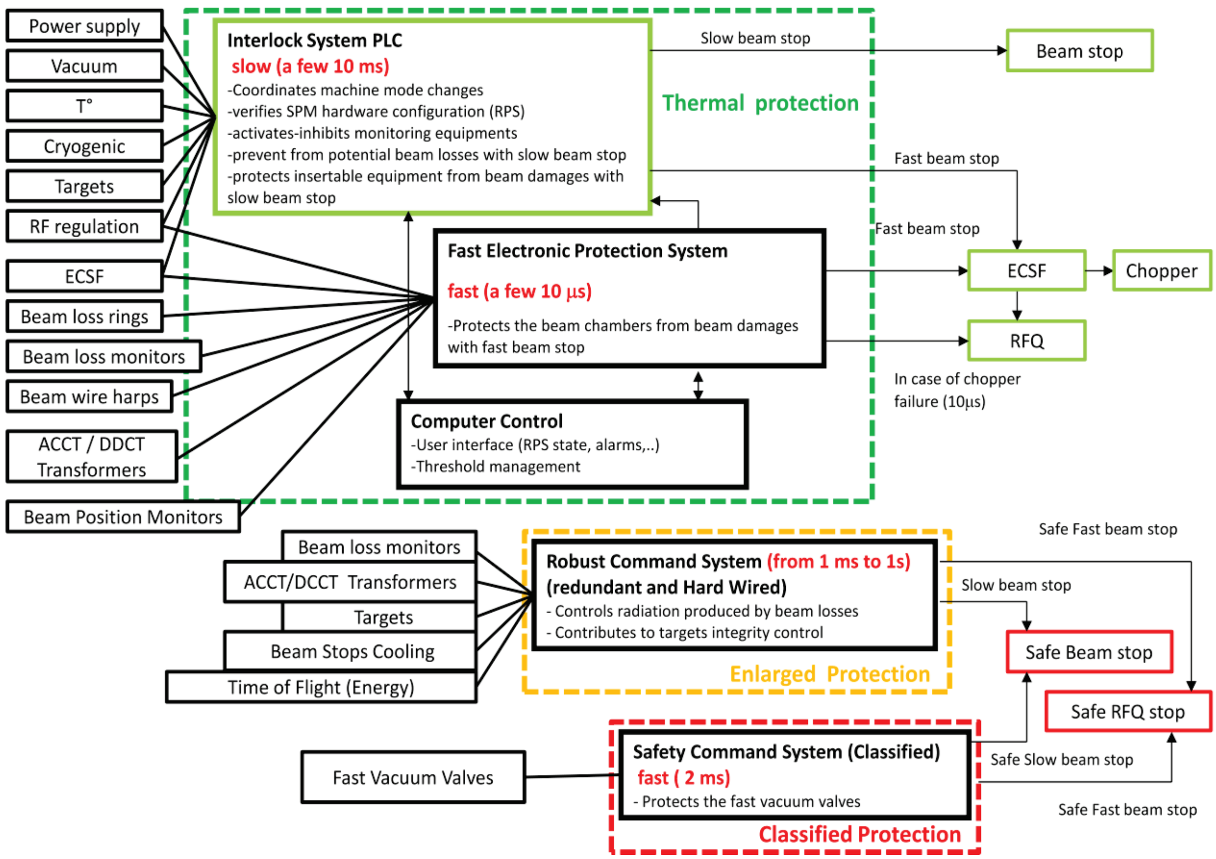

Figure 1: Functional Schem of the SPIRAL2 Machine Protection System, with its three sub-systems: Thermal Protection, Enlarged Protection, Classified protection for fast vacuum valves.

Thermal Protection System

The thermal protection system is constituted of three main components:

1) A PLC (with 1300 Inputs/Outputs) which:

- Coordinates the machine mode changes,
- Verifies the MPS hardware configuration through the Run Permit System (RPS). The Run Permit System enables to define in a secure way the Machine Mode. One Machine Mode corresponds to the choice of one beam type, one beam path along the accelerator and one beam power. These parameters are defined through a secure system based on hard wired keys [5],
- Activates or inhibits the monitoring equipments,
- Prevents from potential beam losses with slow beam cuts, by controlling all ancillary systems like cryogenics, vacuum, etc…
- Protects insertion devices from beam damages by controlling slow beam stops.

2) A fast electronic protection system which:

- Protects the beam chambers from direct beam damages,
- Activates a fast beam cut through the use of the low energy beam line slow chopper.

It receives the alarms from all the beam diagnostics, like loss rings and sleets, beam loss monitors, beam profile monitors, intensity measurements with ACCT and DCCT, beam position monitors, time of flight monitors for energy measurements [6].

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It sends then an order of beam cut to the Beam Time Structure Control Electronic, which commands the slow chopper, and to the RFQ, as shown in Fig. 2.

3) The control system [7] which:

- Automatically checks the machine set of parameters and settings, in coherence and respect with the RPS,
- Allows specific users for managing the various detection thresholds,
- Implements a user interface to increase the beam power in a coherent way with the MPS, keeping track of progressive steps,
- Provides an operator interface for surveying beam losses and beam throughput, also displaying alarms such as beam cuts.
- Displays some general synoptic for interlocks and the beam structure pulse representation.

Enlarged Protection System

This system is a simple and secured one, based on the association of a PLC with a hard wired system. This system relies on the following diagnostics based sub-systems:

- The monitoring of radiation produced by beam losses,
- The operating range control of the facility,
- The beam dump and target integrity controlling set.

It receives alarms from beam losses monitors, beam intensity and energy diagnostics, beam dump and targets control parameters. Therefore, it activates the beam cut through commands sent to safe and slow beam stops in the low energy beam line in association with a temporary RF stop on the RFQ. It based on a redundant hard wired system as show in Fig 2.

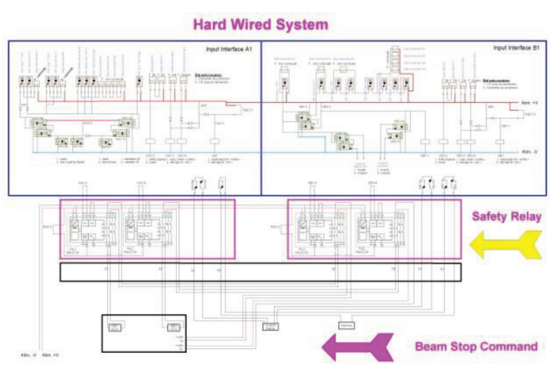

Figure 2: Redundant hard wired system.

Classified Protection System for the Safety Class Fast Valve Protection

The classified protection system is based on the association of a PLC with two redundant hard wired systems. The first one is a part of the Enlarged system, and the redundant part is an electronic device based on a 7400 series chips.

To respect the requirements of IEC 61508 standard, a Failure Mode and Effects Analysis (FMEA) was made to eliminate dangerous failures. The single failure criterion was selected as reliability criterion.

BEAM DIAGNOSTIC ALARM MANAGEMENT SYSTEM

Beam diagnostics are distributed along the accelerator, and most of them are non interceptive, in order to control continuously beam parameters and beam losses [6].

Alarm Management System

The beam diagnostic alarm management system is based on a fast electronic card, which receives alarms from the various diagnostics. These alarms are then gathered on an electronic summation card.

Threshold and Alarm Management

The thresholds for beam loss detection have to be recalculated for each beam, due to the specificity of SPIRAL2, which accelerates a large range of beams, with various intensities and energies. The general control system calculates these thresholds.

CONCLUSION

The SPIRAL2 MPS is currently under design. PLCs and fast electronic cards are under design, for a realization scheduled in 2014. The technical complexity of the SPIRAL2 system is directly linked to the large variety of accelerated beams, in terms of intensities (several orders of magnitude) and energies, and in terms of beam time structure. In addition, one system is classified for safety aspects of the facility which implies a much heavier work load due to quality constraints associated to safety class equipment.

The MPS will have to be in operation for the second semester of 2014, to start the commissioning of the facility.

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