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PROGRAMMABLE LOGIC CONTROLLER SYSTEMS FOR SPIRAL2

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Abstract

PLC provides a large part of the SPIRAL 2 project's commands. The SPIRAL2 project is based on a multi-beam driver in order to allow both ISOL and low-energy in-flight techniques to produce Radioactive Ion Beams (RIB). A superconducting light/heavy-ion linac with an acceleration potential of about 40 MV capable of accelerating 5 mA deuterons up to 40 MeV and 1 mA heavy ions up to 14.5 MeV/u is used to bombard both thick and thin targets. The PLCs provide vacuum control, access control, part of the machine protection system, control of the cryogenic distribution system, cooling controls, control of RF amplifiers, they are associated with the safety control system. The standards used are presented as well as the general synoptic of the PLC control system. The details of the major systems are presented, the Cryo distribution, the machine protection system, a safety system.

INTRODUCTION

Officially approved in May 2005, the GANIL SPIRAL2 radioactive ion beam facility was launched in July 2005, with the participation of French laboratories (CEA, CNRS) and international partners [1]. In 2008, the decision was taken to build the SPIRAL2 complex in two phases: A first one including the accelerator, the Neutron-base research area (NFS) and the Super Separator Spectrometer (S3), and a second one including the RIB production process and building, and the low energy RIB experimental hall called DESIR [2].

In October 2013, due to budget restrictions, the RIB production part was postponed, and DESIR was planned a a continuation of the first phase. The first phase SPIRAL2 facility is now built, the accelerator is installed [4]. The French safety authority agreement is now validated and the accelerator is under testing with the aim of obtaining the first beam in 2019 [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. PLC provides a large part of the SPIRAL 2 project's commands.

THE FUNCTIONS PERFORMED BY THE PLCS

The details of each type of function are indicated with its specificities and main characteristics. The selected architectures are also described for each system. The general overview shows the PLC control system and its organization (Fig. 1). Each color includes the type of process processed by the control system as well as each type of main function processed.

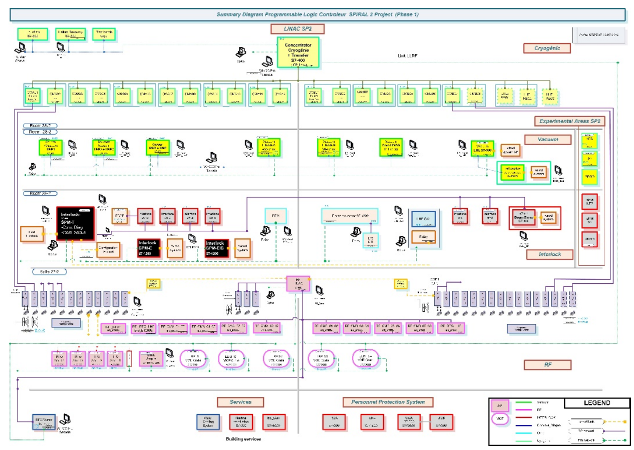

Figure 1: Summary Diagram of the system.

CRYOGENICS

The cryogenics process itself includes several systems: the liquefier, the helium recovery system, the helium transfer line, the cryomodules (19). The liquefier control system has been provided by the subcontractor with a supervision under "PC Vue". This system is linked to two other systems, the helium recovery system, which is used to collect and store evaporated helium in a flexible tank. This system uses a pressure storage and helium purification system to remove pollution after use. The link with the accelerator is made with the helium transfer line control system itself in connection with each PLC (ET 200 CPU) controlling the cryomodules. These systems provide temperature measurements, level measurements and helium level and pressure controls in the cryomodule [3]. A system coordination and centralized interface management is performed by a concentrator PLC that performs these functions as well as the management of the helium transfer line. This control system is completed by a motor control function for controlling the frequency tuning of the RF cavities. Brushless motors were chosen because of their performance, adaptability and ease of integration into PLCs. Win CC Pro supervision was used as the interface to this system. It makes it possible to monitor the state of the system, to effluent controls and to see the state of the sequences of the control graphs and their transitions evolve directly. The amount of data is

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important: 6000 data, 1400 digital inputs and outputs, 200 pages of scada.

MACHINE PROTECTION SYSTEM

This system has been divided into several independent systems [4]. A system (TMPS: Thermal Machine Protection system) provides the so-called thermal protection and interlock functions. It is a system carried out in quality assurance but without any particular requirement of SIL level (Safety integrated level). Another system (EMPS: Enlaged machine protection System) provides the functions of safety protection against beam risks [5]. Another independent and isolated from the others [FCPS: Fast Cut Protection System] also protects fast vacuum valves. The TMPS is associated with the Run permit system functions of the machine. This function, thanks to a lineage panel, allows the machine path to be selected and the stopping points of the beam to be determined in a safe and rudimentary way. This panel also allows to ensure a double check of the machine's configuration by comparison with the computer file containing the machine's configuration. It also controls the time structure of the beam in order to adjust it, and to control the beam power of the machine. One dedicated to enlarged protection, which is based on robust technics, such as PLCs or hard wired system, as it controls the operation domain of the facility from the safety point of view (beam intensities and energies), and the integrity of the various beam dumps and targets, among which actinide targets. This second system has much less constraints in term of response times, situated in the millisecond to second time range.

VACUUM

The PLCs for controlling the vacuum process ensure automatic control and vacuuming for the entire machine. They are linked to a general supervision under Win CC pro. The exchange of safety information takes the form of an exchange of digital inputs/outputs as well as a safety exchange with other processes for the protection of cryomodules or for the interruption of the beam in the event of a vacuum valve closure. The pumping process consists of vane primary pumps, turbo pumps and cryogenic pumps.

RADIOFREQUENCY

One of the PLC [Amplifier] (S7-400) controls the amplifiers of the crymodules and acquires all the operating parameters of the amplifiers of the RF cavities. The RF PLC (S7-400) provides the interlock functions by controlling the process cooling and managing the synthesis of operating authorizations [6].

COMMAND AND CONTROL PERFORMING SAFETY FUNCTIONS

The safety systems are carried out in a standard way by redundant wiring systems whose correct operation control and information feedback as well as status feedback is done by an industrial programmable logic controller gateway (Fig. 2). Depending on the level of operational safety, and depending on the case, either electromechanical relays alone were used or optocouplers in combination with electronic boards using discrete components. The execution is done in quality assurance, with a V-shaped development cycle. A failure mode analysis ensures that the single failure criterion chosen as one of the elements to be met by the control system is met. In case the control system has to provide a process control function and a safety function (in the case of gas storage) [7], an additional independent specific CPU processes the safety system support functions by using a system ET 200 S CPU. Two HMI interfaces are used, one very precise on the basis of the TP 1200 operation display panel and the other, by means of a high-level application adapted to EPICS. The systems treated in this way are the cooling of the accelerator Beam Dump, a radioactive gas storage device and two machine protection systems.

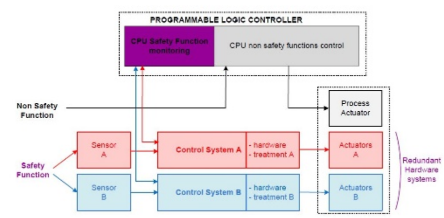

Figure 2: Functional Schem of safety systems.

PERSONNEL SECURITY MANAGEMENT

Machine access management: the case of the access control system is a particular system combining a normal PLC with a safety PLC, all associated with a wired device [8]. This system guarantees the non-simultaneous presence of personnel and the presence of the beam in the machine rooms. Radiation protection beacons in the rooms are in contact with PLCs (redundant or not depending on radiation levels) and cut off the beam or prevent access to the premises if radiation levels are exceeded. The electrical emergency stop triggers are managed by a high availability PLC type S7-400 H (high availability). Two types of security and safety alarms are based on one S7-300 (GAR) and the other on a PLC S7-1500 (ARS) for safety alarms. These systems are backed up on battery power.

HOW THESE SYSTEMS WERE MADE

These systems have been realized through in-kind contributions for injector control systems, or for diagnostic control. The connections, the construction of the rack, the electrical cabinet and the construction of certain wiring diagrams were subcontracted. Some systems have been fully outsourced such as the access management system. The definition, technical studies, functional studies, schematics and software were carried out by the Ganil teams when the order batch was not a contribution in kind.

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THE STANDARDS ADOPTED

All the programmable logic controllers adopted are Siemens programmable logic controllers and are mainly from the S7 1200, S7 300, S7 400 and S7 1500 range at the end of the project. The networks adopted MODBUS TCP for high-level links with EPICS [9]. The fieldbus are mainly Profibus DP. The machine interfaces have been realized on TP1200, scada Win CC Pro or by the EPICS system (SS BOY) and the temporary use of MUSCADE, an IRFU scada software. Use of the PC VUE supervisor for centralized technical management (CTM). Putting PLC equipment in racks in general and more rarely in electrical cabinets. The exchange of safety information in the form of an exchange of digital inputs and outputs. These exchanges are merged by redundant inputs and outputs if the functions are of a high level of safety or security. The control command system is EPICS for this project. The choice of implementation: standardization of programming methods and architectures. Use of operation display panels. Use of winCC Pro scada. Choice of simple architectures adapted to batch production. Use of Siemens brushless motors that are easy to integrate with a PLC. Use of the TIA Portal program editors as soon as it appears. These choices made it possible to facilitate relations with partner IKs, subcontractors and all teams. Not too much intelligence offset or too many offset inputs/outputs due to the presence of neutrons in the linac tunnel that destroy the electronic components.

THE STATE OF PROGRESS

Today, the majority of the systems presented are accepted and operational. Only the thermal protection system is being tested so that it can be definitively accepted for the injection of the beam into the Linac in November. All safety systems are received and operational. These systems are subject to particular vigilance and a thorough and systematic testing procedure. They are the subject of a formal written form and multiple validations. Safety functions are received by a mixed team of automation engineers and safety engineers providing a second-level controller function. The cryomodules control system is in the final stages of development. The functions continue to be adjusted and completed based on the ongoing tests on the Linac. One of the current good results is the keeping of the pressure and helium level regulation specifications of the cryomodules which are currently held in the presence of RF in all cryomodules. Only the control test of the frequency tuning system associated with the cryomodules control system will remain because the LLRF (low level radio frequency) system acts on a tuning correction motor.

ORGANIZATION

It is difficult to gather the necessary resources to build such systems on a project and a machine of this size. The choices must be strategic, taking into account the schedules and skills of the partners, whether they are subcontractors or other laboratories. The choices that have been made are to entrust complete assemblies whose contour of the batch contains the process for the realizations entrusted to the laboratories. The achievements entrusted to subcontractors were of two kinds. Complete batches (process + control system) have been entrusted to subcontractors in the utilities sector. For the accelerator process, the strategy was to entrust subcontractors with the work of producing schematics, connecting and building rack or electrical cabinet. The definition studies, functional studies, software development and testing were entrusted to the project's internal teams.

THE CONCLUSION

Almost all systems are operational. The reliability of the system is remarkable. The technical options chosen are not the most innovative solutions, but we have strong reliability constraints, operational safety constraints associated with limited human resources. As a result, proven technologies have been adopted quite often. Lack of resources has long been a challenge. The development and use of new technologies have been limited to the strict minimum to achieve this control system. Innovative options were chosen when productivity gains were associated with them. The cryogenics and cryomodules control systems and the machine protection system are important achievements. Their reliability is essential for the proper functioning of Linac and design options have been chosen accordingly. For the control of classified devices, wired systems have been favored by excluding the use of systems using software. Malfunctions are more easily analyzed and demonstrated. For these systems, sensors and processing systems are systematically redundant. One system operates in positive logic while the other operates in reverse. All these safety systems are now approved and operational. Authorization to start the machine is granted. The Linac is in cold, the RF is gradually put in each cavity. The first beam accelerated by this new Linac is expected at the end of the year.

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