THE SPIRAL2 RADIOFREQUENCY COMMAND CONTROL

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Abstract

Mainly for carrying out nuclear physics experiences, the SPIRAL2 facility based at Caen in France will aim to provide new radioactive rare ion or high intensity stable ion beams. The driver accelerator uses several radiofrequency systems: RFQ, rebunchers and superconducting cavities, driven by independent amplifiers and controlled by digital electronics: the low level radiofrequency subsystem which is integrated into a regulated loop driven by the control system. A test of a whole system is foreseen to define and check the computer control interface and applications. This paper describes the interfaces to the different RF equipment into the EPICS based computer control system. CSS supervision and foreseen high level tuning XAL/JAVA based applications are also considered.

SPIRAL2 AND RF CAVITIES

The SPIRAL2 project is originally designed to produce new intense rare ion beams (RIB). The main production scheme is based on fast neutron induced fission of uranium target using a carbon converter. The driver accelerator facility composed by sources, followed by a Radio Frequency Quadrupole (RFQ), 3 bunchers, and a superconducting linear accelerator (LINAC) will be able to accelerate also proton, deuteron or heavy ion beams. The LINAC will be composed of 26 quarter wave superconducting resonators closed into 19 cryo modules. All cavities will be driven by independently power amplifiers at 88.0525 MHz [1].

COMMAND CONTROL MAIN CHOICES

Two kinds of users are identified today. On one hand beam drivers and operators working in the control room are in charge of delivering beams. On the other hand, engineers have to make sub systems and equipment working even if the general control command system is not available.

Figure 1 gives an overall view of process control architecture. As usual command control systems, two main layers can be identified. The supervision layer provides high level tuning applications, supervision screens and specific human interface tools. The process control layer provides access to different actuator and feedback information generated by sensors.

For the command control room, and control process associated, EPICS was early chosen to ease development and integration of software components developed by all laboratories involved in the SPIRAL2 collaboration. Industrial PC Linux or VME Vxworks crates will host EPICS input output controllers (IOCs) [2][3].

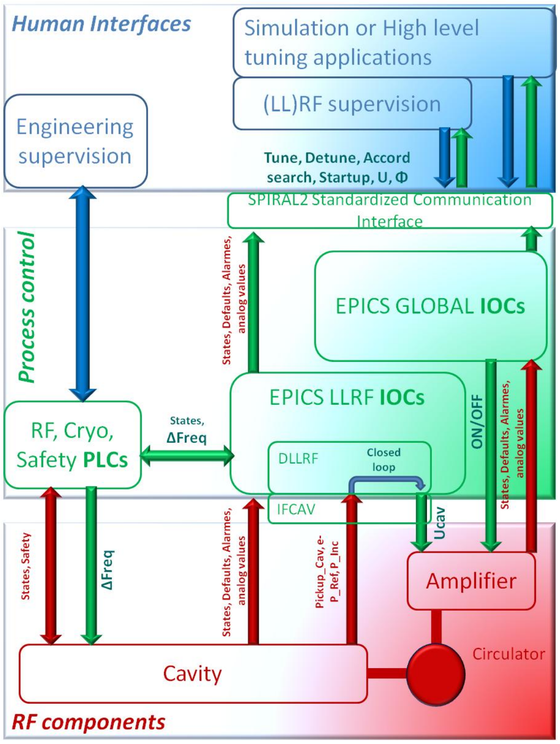

Figure 1: Main RF CC functional architecture.

Siemens S7 programmable logic controllers (PLCs) will be dedicated to slow control material protection, safety and local engineering applications. On one hand, supervision screens are produced with EDM or CSS/BOY, on the other hand more sophisticated high level tuning applications derive from the Java XAL framework [4][5].

To control Radio Frequency (RF) equipment, a dedicated command control (CC) sub system is identified. The main piece of this sub system is a low level radio frequency (LLRF) control process which will regulate the accelerating field of each cavity with a fast automatic closed loop [6].

POWER AMPLIFIERS

Amplifiers foreseen to drive RF cavities will be able to deliver up to 20 kW for solid state amplifier and up to 60kW for tube amplifiers. Both are provided by industrial companies and a special care has been taken on prototyping and testing. To ease engineering support, supervising PLCs applications are delivered with. A special care is going to be taken for putting the tests with EPICS components that will be used for the final command control [7].

Figure 2 shows the CSS/BOY supervision screen developed for bench tests of tube amplifiers.

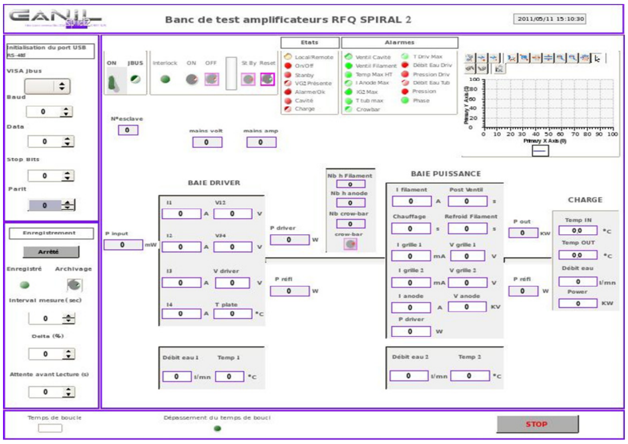

Figure 2: Tube amplifier supervision screen.

LLRF CC

The LLRF will mainly provide the control analogue signal to each cavity's amplifier. Among others, it will also control the frequency, the start-up in an automated way, and will monitor the electric arc phenomenon. In order to fulfil these functionalities, the first digital subsystem (DLLRF) will acquire and process data from the second subsystem (IFCAV) which will host RF components to interface cavities. In addition to control the amplitude and phase, the DLLRF will be in charge of communicating with global command control applications throw a standardized interface. To ease the integration in the whole command control architecture, technical choices for this sub system respect the main EPICS and VME command control choices.

PROCESS CONTROL

VME Process Control

To ease high level application access to the process control layer, a SPIRAL2 standardized communication interface has been designed [8]. Dedicated RF applications will tune a cavity with the U voltage value and the Φ phase value. The EPICS channel access (CA) protocol and this standardized interface enable applications to discover equipment remote values, and lists of state, defaults, and alarms.

Global EPICS IOCs aim to interface specific RF equipment command to supervision layer. They could also be an interface to LLRF EPICS IOCs that include all specific cavity functionalities.

Implantation Diagram

Figure 3 shows implantation diagram designed for RF command-control. This implantation could evolve before final integration of each command control component, engineering needs, like cable path or command control crate, are nearly well identified today.

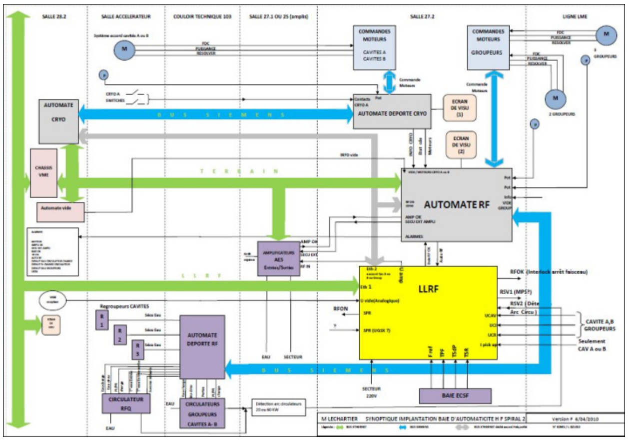

Figure 3: Implantation diagram.

PLC Process Control

In addition to general functions described above, PLCs take a particular place for RF command control. Amplifiers will be interfaced via dedicated PLCs solution. In the same way, a well tuned and regulated cavity which drifts in frequency should be adjusted by mechanical or thermal constraint. As shown on figure 1, for the special case of mechanical according cavity delta frequency, dedicated brushless motors driven by PLC are under prototyping.

HUMAN INTERFACES

Introduction

To drive a machine like the SPIRAL2 facility, a set of high level and supervision applications as shown on figure 4 are going to be developed [9]. After configuring equipment, conditioning dedicated sub systems like RF equipment, and setting theoretical beam values, RF equipment can be tuned and optimized for different kind of beams. CSS/BOY applications will assume to put each equipment and servitudes into work when more complicated JAVA XAL applications will tune the machine.

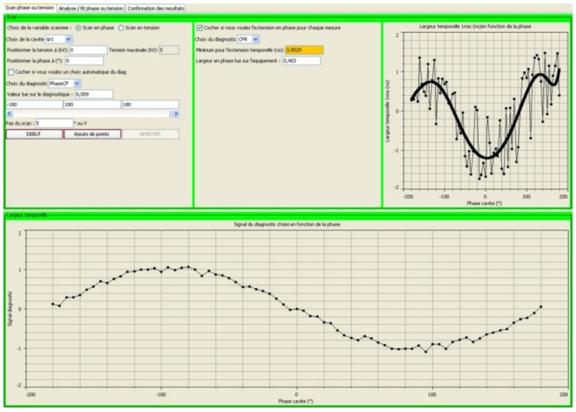

Figure 4: Cavity tuning application (preliminary).

High Level Applications

Two steps are foreseen to tune rebunchers and LINAC cavities.

At first, consigns will be set on cavities and associated quadrupole magnets, one after the other, with an application named "Cavity tuning" shown on figure 4. Theoretical values come from simulation application software named GenLinWin [10] developed by “D.URIOT et al.” at CEA. Scans around theoretical amplitude and phase values associated with a time of flight measure value will be used.

Secondly the “Optimization” application shown on figure 5 will adapt the beam to the channel created, using the three rebunchers and four quadrupole magnets.

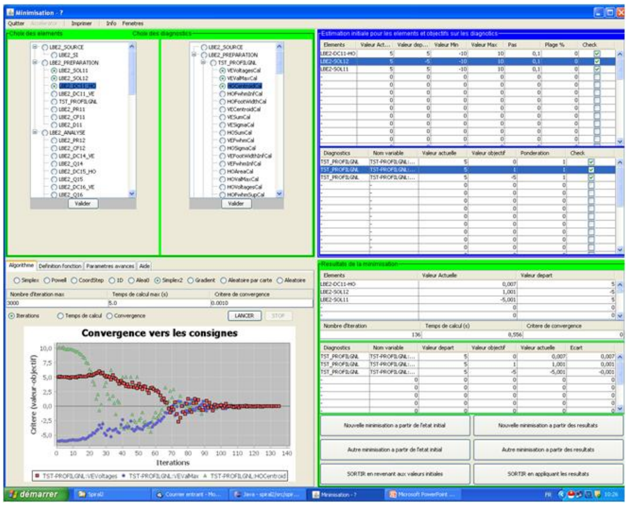

Figure 5: Optimization application.

REBUNCHER CC TESTS

Rebunchers (figure 6) used on the medium energy line have been prototyped at GANIL. Power tests started in 2010 have been performed till July 2011 [11]. They have confirmed the Q factor, the shunt impedance and maximum substained voltages as well as cooling and coarse tuning capabilities.

Figure 6: Rebuncher prototype.

The next step planned on the beginning of 2012 will qualify this cavity with the whole LLRF and CC systems. LLRF sub system has already been used on partial test-bench platforms to qualify the two families (A and B) of the LINAC cavities. Furthermore, setting and validating the whole command control during these tests will be an essential step before the final integration phase. To achieve this task, special RF CSS/BOY supervision screens to control the rebuncher will also be developed.

FIRST RESULTS AND NEXT STEPS

RF command control architecture is today well seen and designed. The tests already made on the amplifier bench have confirmed the interface between IOCs and PLCs. First LLRF tests on cavities A and B have shown that first command control prototype components reach projected performances. Simulations on the first RF tuning applications confirm the choice of XAL/JAVA. Brushless motors prototype is nearly well known now and next rebuncher tests should confirm the whole command control system. After that, the strategy to integrate the definitive command control should be confirmed.

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