LLRF SYSTEM FOR A NOVEL, COMPACT, SUPERCONDUCTING CYCLOTRON FOR RADIOISOTOPE PRODUCTION*

D. Gavela#, J.M. Barcala, A. Esteve, A. Guirao, J. Marín, C. Oliver, L. García-Tabares, F. Toral, C. Vázquez, CIEMAT, Madrid F. Pérez, A. Salom, CELLS, Cerdanyola del Vallès

ABSTRACT

The AMIT cyclotron will be a 8.5 MeV, 10 µA, CW, H- accelerator for radioisotope production, including a superconducting, weak focusing, 4T magnet, allowing for a low extraction radius and a compact design. The accelerating cavity is a 60 MHz, quarter wave resonator powered by a modular 8kW solid state amplifier. The main requirements for the LLRF system concern the stability and resolution of the frequency (1 kHz) and the cavity voltage (0.3%). It was conceived to be simple, cheap, easily integrated into the global cyclotron control system and to take advantage of some components already available in our institute. The system consists of a modular box mainly including commercial sensors for measuring the amplitude and phase of the signals, a fast interlock system governed by reflected power and the drivers for the movement of the stepper motors for the cavity tuning. The RF signal is generated by a commercial signal generator. The control logic is integrated in the Siemens PLC responsible for the control of all the systems of the cyclotron. Two main control loops (cavity voltage and cavity tuning) are performed. The main features implemented in the GUI are the possibility of working in closed loop (cavity voltage regulation) or open loop (SSPA power regulation), automatic or manual tuning of the cavity, ramps and automatic conditioning based on vacuum pressure.

AMIT PROJECT

• Positrom Emission Tomography (pet)

AMIT CYCLOTRON RF SYSTEM

RF cavity – 60 MHz quarter wave Optimization











AMIT cyclotron
magnet on magnetic
field measurement
test bench
developed by ALBACELLS in
collaboration with
Ciemat

resonator with 60 kV gap voltage







• Cavity tests and conditioning

Minimum frequency (plungers up)	60.150 MHz
Maximum frequency (plungers down)	60.375 MHz
Q_L	2,333
Q_0	4,763
Coupling factor	1.042
R _{shunt}	303 <u>kΩ</u>
Expected fordward power at 60 kV	5.93 kW
Expected pickup power at 60 kV	32.0 <u>dBm</u>



 Amplifier: BTESA 8 kW SSPA 4 modules x 2 kW



Conditioning at ALBA synchrotron RF lab

LOW LEVEL SYSTEM

Requirements:

- Frequency stability and resolution: 1 kHz
- Cavity voltage stability: 0,3 %
- Phase stability: 1º (standalone system -> no need for synchronization)
- Arc protection: fast RF cut through reverse power signal

PLC:

- Same PLC as AMIT cyclotron general control system
- Receives the RF power and phase signals from the RF box
- Carries out the amplitude control, which can bet set to closed loop (cavity voltage regulation) or open loop (power out of the SSPA or drive signal regulation)
- Carries out the tuning control (closed loop based on phase of cavity pickup signal) or open loop with manual movement of the tuners.
- Directly receives the cavity temperature and tuners end of stroke and potentiometer (position) signals and carries out the corresponding protection logic.
- User interface allowing for ramps, automatic conditioning governed by cavity vacuum pressure, time graphs of all the measurements.
- Receives from RF box the power signals (forward, reflected, pickup, drive) and the phase signal for cavity tuning
- Communicates with the motors driver (installed inside RF box) through Profibus.
- Sends to the RF box the reference signal for the reverse power interlock

RF hardware box:

- Receives the RF signals from the cavity
- Carries out the signals adaptation, and the measurement of RF parameters through commercial SMA detectors or evaluation cards
- Carries out the fast arc interlock (based on reverse power actuating through a pin diode). RF is cut in less than 100 ns

SIMATIC WinCC flexible Runtime		910 000			
GOBIERNO DE ESPANA Y COMPETITIVIDAD COMPETITIVIDAD	RADIOFRE	CUENCY SYS	ТЕМ	1:43:47 PM 10/11/2017	
ON OFF RS	GLOBAL RST)FF		CLOSE Default Values Management	
SSPA & LLRF Amplitude Loop MANUAL SAVE AS DEF. LOAD DEF. Voltage Δ Change Rate Δ 67.9277 + 1.0000 + 1.0000 kv/s 67.9277 setpoint Kv 0.001587 Kvp (kw/kv^2) 0.0000 offset (Kw) 95.0000 + 1.0000 * 10.0000 + 1.0000 %/s 95.0000 + 1.0000 % 10.0000 + 1.0000 %/s 95.0000 + 1.0000 % 10.0000 + 1.0000 %/s 95.0000 Applied Value % 5.0000 Gen. Max. Voltage (V) Max. Ref. Pow. Phase Loop MANUAL A Central Max. Ref. Pow. S9.884 + 0.001 MHz 60.134 MHz 0.00 %	Alarms SSPA SSPA Power Ready SSPA Ready SSPA Cooling Alarm Fan Warning Pump Warning SSPA Amplifier fail SSPA Amplifier fail SSPA Amp. War. Alarms LLRF LLRF Gen. Comm. LLRF Gen. Error LLRF Ref. PowerHW LLRF Tuners Driver	Internal Interlocks Vacuum System Magnet System Water System Vautoshield Opened ISOLATED MODE External Interlocks Emergency Stop Radiation Detector Vault Open	Cavity Voltage (Pt VCav) Indicent Porwer (Pd) Reflected Porwer (Pr) Injected Power (Pi) Phase difference Pt - Pi Tuned Phase SSPA OUT ON Power Ready RF Ready RF REVEL OK : SSPA	4.640 7.323 kW 67.928 kV 4.640 7.808 kW 4.640 0.890 kW 4.640 8.795 W 0.000 5.0 ° se Point 0.0 ° F OUT ON Gen. Amp. 4.7500 V Gen. Freq. 59.88 MHz	
RF CAVITY Temperature Limits Tunners Speed RF Water IN 30.0 9C Slow 1000.00 Hz RF Water OUT 30.0 9C Slow 1000.00 Hz Cavity T1 30.0 9C Fast 2000.00 Hz Cavity T2 30.0 9C Manual Tuner Cavity T3 30.0 9C IN OUT Cavity T4 30.0 9C Cavity T6 30.0 9C 2000.00 9C	Alarms Cavity Temp. Alarm HW Limit S. Alarm Tuner Pos. Alarm	TemperaturesRF Water IN23.6RF Water OUT20.0Cavity T123.6Cavity T223.4Cavity T322.5Cavity T422.0Cavity T525.0Cavity T621.5	Manual Tuner PC PC PC PC PC PC PC P	Automatic Tuner	
New Alarms & Warnings Alarms & I Time Date Status Message I 1:37:01 PM 10/11/2017 E ALARM in CRYOGENICS system - VACVISION ERROR Warnings I 1:31:50 PM 10/11/2017 ES ALARM in RF system - SSPA RF Level OK I 1:29:34 PM 10/11/2017 ES ALARM in RF system - CAVITY Temperature 4 Temperature 4					





- Tuners motors driver is included inside RF box, although governed by PLC
- RF drive signal produced by a commercial laboratory signal generator by the mooment





RF signals treatment (cards to be installe inside RF box)



Arc interlock switch time measurement



Phase signal calibration



Laboratory measurement setup

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Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas