PROGRESS IN DEVELOPING A PLC CONTROL SYSTEM FOR THE PKUNIFTY *

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Abstract

A compact remote PLC control system has been developed for the PKUNIFTY (Peking University Neutron Imaging FaciliTY). That facility is based on a 2 MeV deuteron RFQ accelerator. The PLC control system has been successfully used for the injector including ECR ion source and LEBT, and it worked reliably last year. Now the control of RFQ cavity, HEBT and Be target has been completed and tested. The interlock system has been enhanced. A low level RF control system, including the auto frequency control (AFC) and auto gain control (AGC) circuits, has been designed for the RFQ's RF power system. Those circuits will work as a lower controller of the PLC control system. The main running parameters can be controlled by setting any desired range of values on the HMI. Test results of hardware and software are presented.

INTRODUCTION

A thermal neutron imaging facility, Peking University Neutron Imaging FaciliTY (PKUNIFTY), is being constructed in Peking University [1-2]. It consists of a D^+ ion injector, a 201.5 MHz mini-vane four-rod radio frequency quadruples (RFQ) accelerator and a high energy beam transport (HEBT). The accelerated D^+ ions are used to produce neutrons by D-Be reaction.

The D^+ ion injector, including a D^+ ECR ion source and a low energy beam transport (LEBT) with two solenoids, has been constructed and tested. It can deliver 50 mA (peak current) of D^+ ions beam with kinetic energy of 50 keV for the RFQ. The normalized rms emittance should be less than 0.2 π mm·mrad and the duty cycle is 10% with maximum pulse duration of 1ms. The detailed parameters could be found in [3-5].

A compact remote control system based on SIMATIC S7-300 PLC has been developed for the PKUNIFTY. It includes two 315-2DP CPUs with software redundancy, some standard I/O modules and communication modules, and a human-machine interface (HMI) software. The HMI software is designed with the SIMATIC WinCC V6.0, which is bound with the SQL database for data access. The first part of the control system for D^+ ion injector has been completed [6] and worked reliably since last year.

The control of RFQ cavity, HEBT and Be target has been completed. A low level RF control system, including the AFC and AGC circuits, has been designed for the RFQ's RF power system. On the other hand, safety interlocks for the facility and environment have been optimized and enhanced. Some test works are in process.

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AFC AND AGC SYSTEM DESIGN

The mini-vane four-rod RFQ will operate at 201.5 MHz and its inter-vane voltage is 70 kV. These parameters must be stable in order to achieve the optimum performance of the RFQ. However, the resonant frequency would be changed due to temperature variation, and the inter-vane voltage would be affected after detuned. A fast automatic RF control system including AFC and AGC circuits should be designed [7-8]. PLC is not fast enough to setup an AFC and AGC system, but its communication function is powerful. So we design an AFC/AGC circuit board based on C8051F12X series microprocessors as a lower-level of the whole control system.

The layout of the AFC and AGC system is shown in Fig. 1. Although AFC and AGC loops are relevant, they can be discussed respectively as their functions are separate.

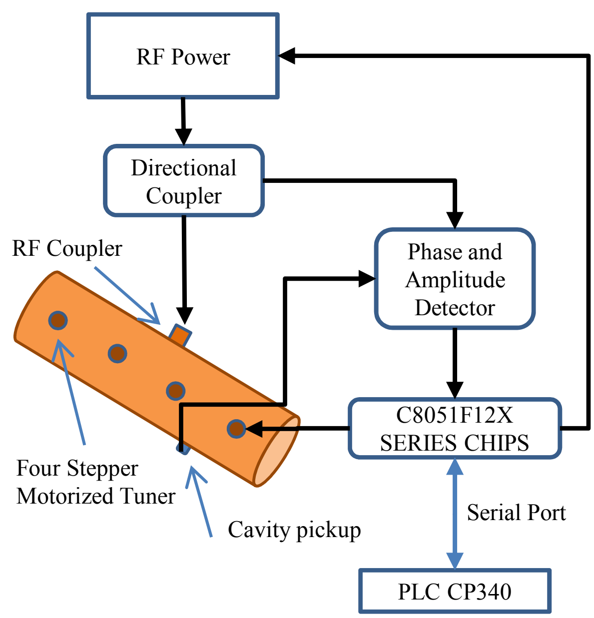

Figure 1: Layout of the AFC and AGC system.

AFC Loop

In order to adjust the resonant frequency of the cavity, a feed-back signal must be found. During operation, the frequency of the RF power source is fixed at 201.5MHz. If the RFQ cavity resonant frequency changed, the amplitude of the pickups and the phase difference between forward pickup and cavity pickup will change, too. The amplitude is related to both power transmission and reflection, and it could only tell whether the system is detuned. However, the phase difference indicates whether the cavity is detuned and which direction to tune the resonant frequency back to 201.5 MHz. So we choose the phase difference as a feed-back signal.

Four stick tuners driven by stepper motors, which are located evenly along the RFQ, are used to compensate the frequency variation. The frequency shifted by the tuner is studied by cold mode test, which is almost linear to the tuner's depth in cavity, shown in Fig. 2.

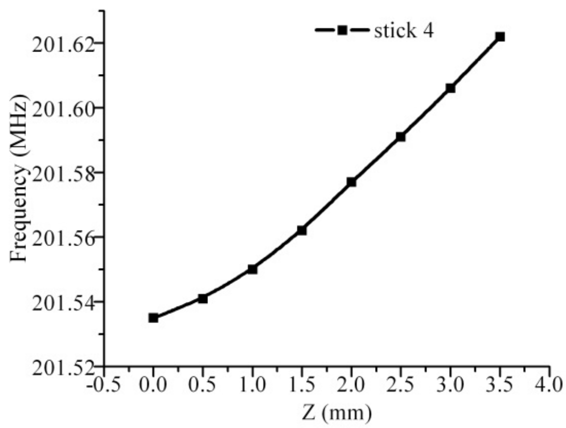

Figure 2: Frequency shift caused by the fourth stick tuner

AGC Loop

The feed-back signals of the AGC loop are forward pickup, backward pickup and cavity pickup. These three signals indicate forward RF power, reflected RF power and RF power in the cavity. The attenuation of these pickups are -66.7dB, -65dB and -50dB respectively.

An AFC/AGC circuit board is designed in order to achieve the above functions. The schematic of the board is shown in Fig. 3.

- Three C8051F121 microprocessors are used to process RF power pickups which are detected by an AD8361, another microprocessor is used to process pickup phase information, and the other one is used to control four stepper motors.
- One C8051F120, which works as a main microprocessor, communicates with the other microprocessors. The main microprocessor evaluates all the data, controls the gain controller and gives instructions to the microprocessor controlling stepper motor. The main microprocessor also controls a serial communication port circuit.
- All the pickup signals are attenuated and isolated to protect the circuit from possible dangerous high power pickups.
- The AFC/AGC circuit board, which works as a lower level controller of the PLC control system, sends data to the PLC and receives instructions from HMI.

SAFETY INTERLOCK

There will be a strong radiation dose in the hall of PKUNIFITY as the designed neutron source strength is $4*10^{12}$ n/s. The enhanced safety interlock can prevent access by anyone (including operators) into the hall while effective dose equivalent above 5 μSv/hour. Radiation monitoring is accomplished by two dual monitors, for neutrons and for gamma/X-rays. The neutron detector consists of a ^{3}He chamber placed in the middle of a polyethylene sphere. The gamma/X-ray detector is Geiger-Muller type. One dual detector is attached to the wall at a height of 1.4 m and near the Be target. The other is movable and can be placed any interest point. The display unit is in the control room. It has all detectors dose rate displays and digital signal alarms.

The interlock system includes two emergency buttons placed in the hall and in the control room respectively,

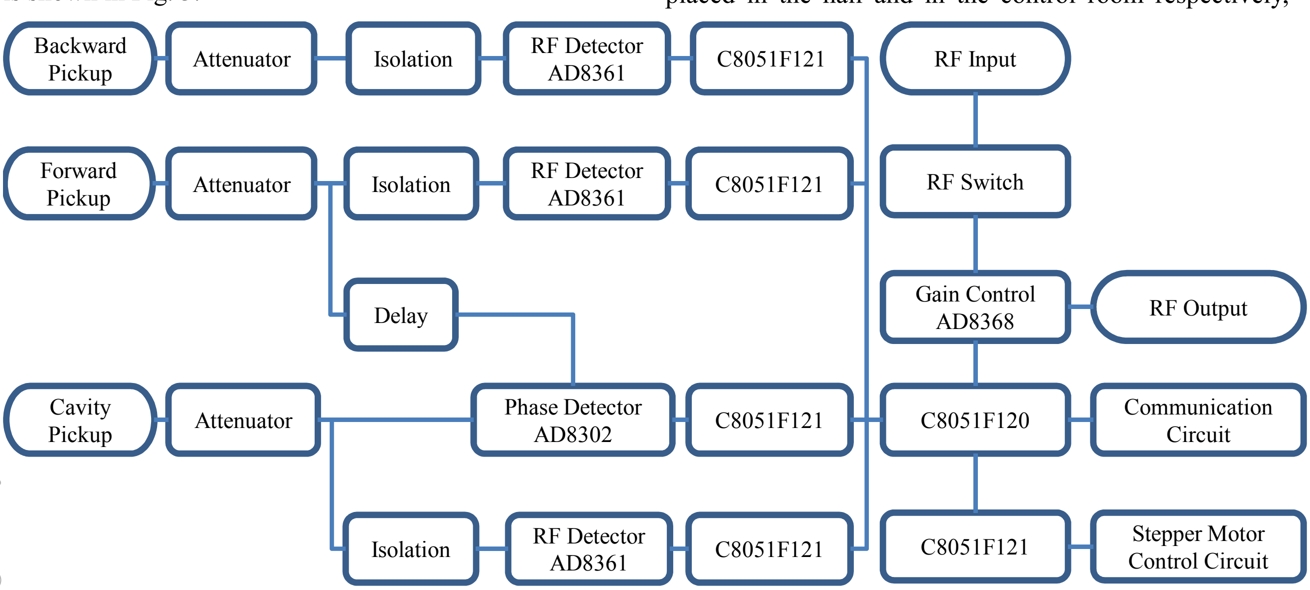

Figure 1: Schematic of AFC/AGC circuit board.

two patrol switches, warning lights, and two proximity switches on the wall and doors of the hall. The schematic of interlock system is shown in Fig. 4.

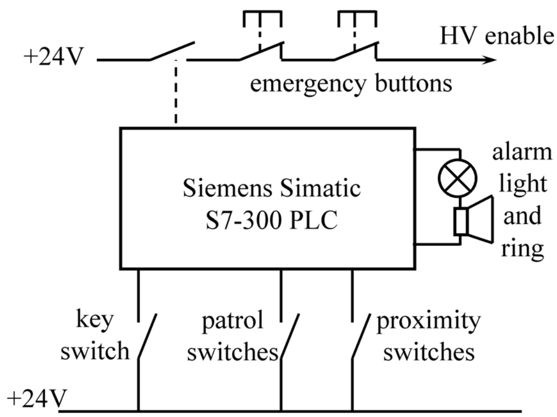

Figure 4: Schematic of interlock system.

There is a key to enable the whole facility. It must be sure that the hall is patrolled and the doors are closed before to turn on the Glassman high voltage power supply for the extraction of D+ ion source. The warning lights will work when the dose rate is above the limit and digital alarm signals are sent to PLC by the dose rate display unit.

If any door of the hall is opened while the beam is enabled, the interlock system will ring a sound alarm and shut down the Glassman high voltage power supply immediately. If this happens, the patrol switches will be reinitialized, operators must patrol the hall again before the HV power supply can be activated.

The emergency buttons are non-powered normal-connect switches installed in enable signal circuit of the HV power supply in series. If they are pressed down, the power supply will be shut down directly without PLC process.

A video monitoring system installed in the hall of the facility provides an additional safety measure. Users in the control room can monitor the whole hall visually. When they find any exception of equipments or human accesses, they can shut down the facility manually by pressing the emergency button in the control room.

DISCUSSION

Some software and hardware measures are introduced for stability and safety of the system.

As the RF power is not in CW mode, we should not detect pulse intervals or pulse rising and falling in order to get precise high power data. So, hardware pulse triggers of the AD8361 microprocessors are activated, and a software delay is introduced.

Margin thresholds are introduced for AFC and AGC loop respectively in order to keep the system more stable because small phase or rf power shift would be tolerable. The margin thresholds are adjustable for different system sensitivity, and they need be determined by experiments.

Each stepper motorized stick tuner has two safety limiting switches in order to protect the bellows which cannot be pressed or stretched too much.

Now the AFC/AGC circuit board has been produced and it is under commissioning.

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