PLC CONTROL SYSTEM FOR VACUUM AND 20 kW RF AMPLIFER

Huisu Kim†, Jongchul Lee
Department of Energy Science, Sungkyunkwan University, Suwon, Korea
Mitra Ghergherehchi, Sangchul Mun, Ho Namgoong, Donghyub Ha, Jong- Seo Chai*
College of Information & Communication Engineering, Sungkyunkwan University, Suwon, Korea

Abstract

Since 2015, the Sungkyunkwan University has been upgrade 10 MeV cyclotron (SKKUCY-10) prototype for producing radio isotopes. For stable and robust cyclotron operation, local controller is main issue. Especially, RF and Vacuum is main part for control system and each sub system fault result in damage to the other sub systems. To solve those problem, we integrate RF amplifier and vacuum local controller by LS PLC (Programmable Logic Controllers). Integrated Interlock event is also processed at one controller. This paper describe system requirement for RF amplifier and vacuum and discuss the detailed design and software development by PLC programming at SKKUCY -10.

INTRODUCTION

Robust and reliable SKKUCY-10 control system is required to operate stably cyclotron for produce radioisotopes. During several year, Sungkyunkwan University has been develop and test SKKUCY-10 prototype control system. SKKUCY-10 controller has one Compact-RIO main controller and several local controllers that include magnet, RF and Ion source hardware [1]. SKKUCY-10 main control system was implemented to realize supervisory Control and Data Acquisition (SCADA). At operating by main controller, RF AMP and vacuum subsystem faults and sequence error sometime result in critical damage to other subsystem such as RF power generation at low vacuum level. To solve those problem, we replace RF and vacuum local controller to one integrated PLC. Developed PLC controller was implemented based on RF, vacuum system requirement and operation sequence.

SYSTEM REQUIREMENT

Figure 1 show the scheme of RF and vacuum system. Integrated vacuum and RF control system require to operate and monitor all hardware. It also require interlock function to protect each machines from damage during operating cyclotron. To fulfil requirement of controller each SKKUCY-10 RF and vacuum system analysis was implemented and based on analysis, interlock mechanism was developed.

RF AMP Requirement

SKKUCY-10 three-stage RF amplifier consist of pre-amplifier, intermediate power amp (IPA) and Power amp (PA). Through tree-stage RF amplifier, RF power is amplified to 20 KW. In SKKUCY-10 RF amplifier, 350V IPA and 7500V PA Vacuum tube anode power supply were required [2]. Heating for Electron emission from cathode was considerable for warming-up procedures. At least 120 second filament warming-up time was set for stable vacuum tube performance. RF amplifier interlock is also considerable parameter for protection from high voltage. Overload parameter from each cathode current and VSWR value is used for major Interlock parameter for amplifier.

VACUUM Requirement

Dual vacuum pump architecture is main properties of SKKUCY-10 vacuum system. Dual vacuum make it possible to decrease time to reach high vacuum level (10^{-6} Torr) and also machine fault probability. Two diffusion pump and two rotary pump are connected through magnet valley holes. At initial step to make vacuum state, rotary pump are used. Using Rotary pump, 10^{-2} Torr Vacuum level can be reached. After reached those low vacuum level, diffusion pump are operated. Vacuum level mainly determine state of vacuum system. According to vacuum level and pump states, roughing, foreline and gate valve are operated.

Interlock

In order to machine protection and personal safety, each system interlock conditions and system interaction during high power RF test were considered. Table 1 show RF and vacuum signal and condition for interlock.

Table 1: Signal and Condition for Interlock

Value	condition	Event
VSWR OVELOAD	PA over Voltage	RF oscillator off
IPA&PA OVERLOAD	IPA & PA Cathode over current	RF oscillator, &PA off
PA Water flow status	Flow rate	RF oscillator , HV off
PA air cooling status	Contact switch off	RF oscillator , HV off
Pump status 1&2	False	RF oscillator off
Vacuum status	Vacuum level	RF oscillator off
EMERGENCY STOP	Ture	HV off

*jschai@skku.edu

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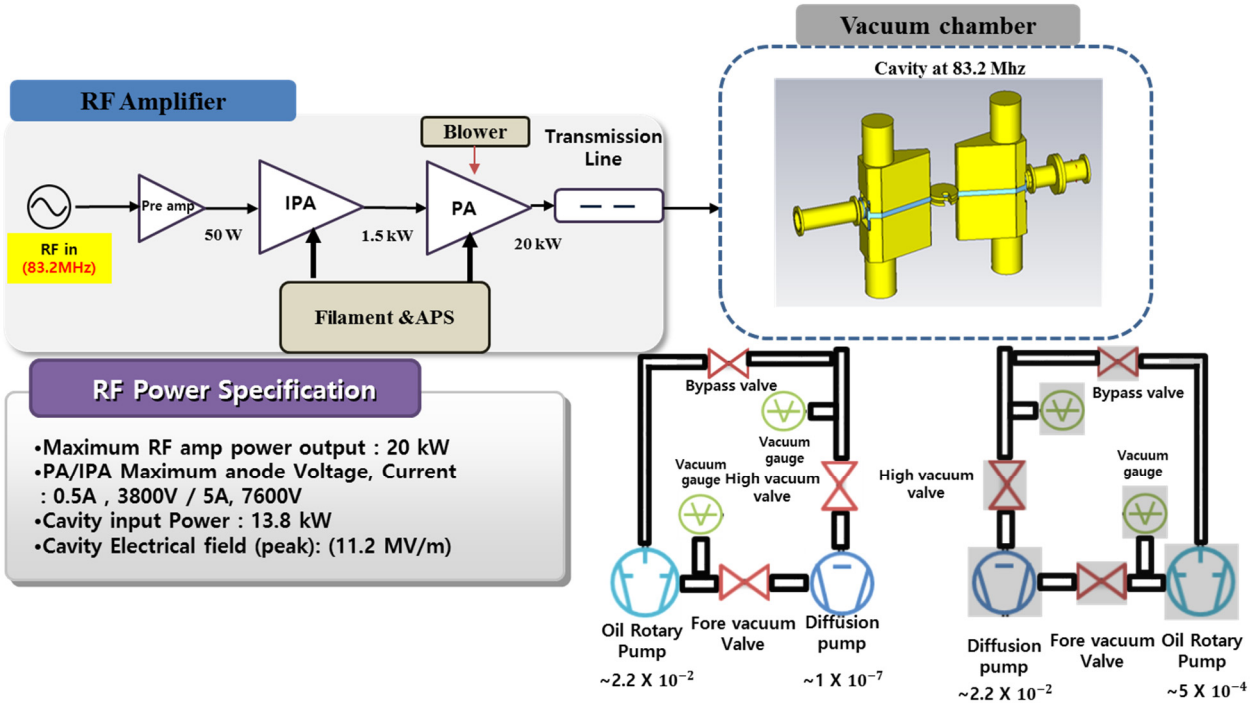

Figure 1: Architecture of RF AMP and vacuum system.

To conduct high power RF test, there are two type of event for Interlock exist. One object of interlock event is to protect from vacuum status fault to damage AMP and cavity and it is possible by switching off oscillator. VSWR overload protection was implemented by VSWR board in Figure 2. To detect VSWR overload its op amp circuit compare Voltage from direction coupler with reference voltage. VSWR board output consist of digital output to indicate VSWR interlock and RF detector voltage that is adjusted to PLC voltage input module range. Other object is protection from amp itself fault. Amp fault include high voltage overload and cooling status of AMP and it is prevented by shutting off power amplifier high voltage.

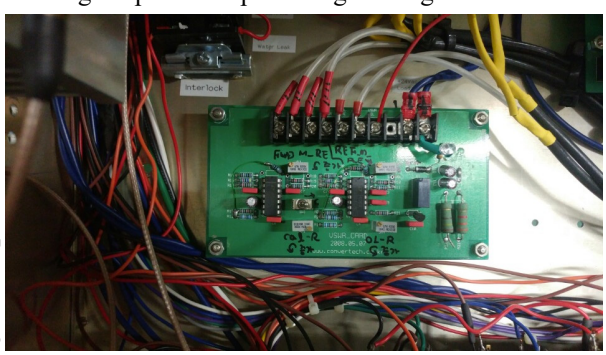

Figure 2:VSWR board for VSWR overload.

Operating Procedure

Vacuum and RF AMP operation sequence start from making low vacuum state in SKKUCY-10 chamber. Oil Rotary pump can reach 2.2×10^{-2} torr. Transition condition to operate diffusion pump is determined by chamber vacuum degree (5×10^{-2} Torr). In our system, we set 5×10^{-6} Torr in SKKUCY-10 vacuum chamber as RF amp operation start-up condtions. RF amp operation is start from air cooling of AMP rack. air cooling, filament and anode power supply is turned on according to sequence of amp operation steps. To Intergrated operating procedure realization. Periodic check for interlcok condition and machine states are required

CONTROL SYSTEM IMPLEMENT

Due to the cost efficiency, stability and reliability, PLC is employed for platform. In our controller, The XGB series PLC was used and its main unit is XBC-DN64H. It has 32 DC 24 input point and 32 transistor output point. Input units default response time is 3 ms and on/off voltage is DC 19V/6V. Output unit response time is within 1 ms. PLC Main unit is used to realize sequence and interlock function of controller. The other used modules are 4 channel XBF-AD04A and XBL-EMTA. XBF-AD04A is analogue voltage and current input module that can be select by switch [3]. Its voltage input range is from 0 V to 10 V and current input range is 0 ~ 20 mA. This unit is used for measuring pressures and RF power. Figure 3 show ladder diagram of Vacuum pleasure calibration from Analog input module.it convert from voltage to digitalized vacuum value.

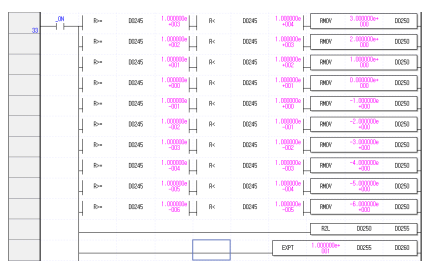

Figure 3: Ladder diagram of Vacuum pressure calibration from XBF-AD04A module.

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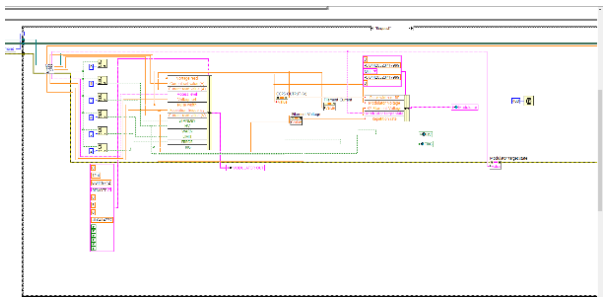

Figure 4: Ladder diagram of auto operation mode.

XBL-EMTA is 100 Mbps Ethernet communication module for remote control. LS PLC Modbus TCP/IP protocol was used for communication between LS PLC as shown in Figure 4 and main control platform (NI – Compact RIO). Realization of Human Machine Interface (HMI) is based on producer/consumer design pattern and it is also made for main control program of SKKUCY-10 cyclotron. HMI for AMP & Vacuum control is shown in Figure 5.

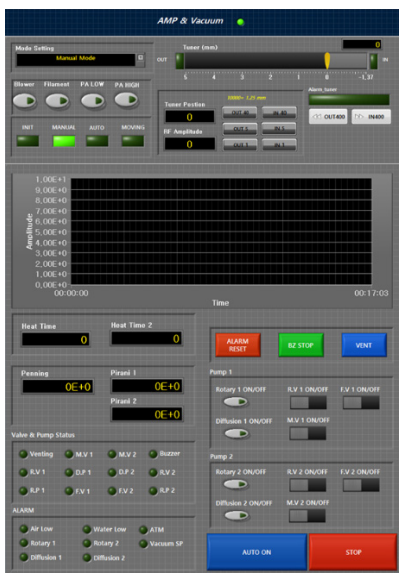

Figure 5: HMI for AMP & Vacuum control.

In HMI, manual & auto sequence is selected by “AUTO ON” button Automation process is implemented in XBC-DN64H PLC. Digital input and output variables is mainly used for auto scan code. Timer and comparison operator is used for timing delay for each step and condition for next step as show in Figure 6.

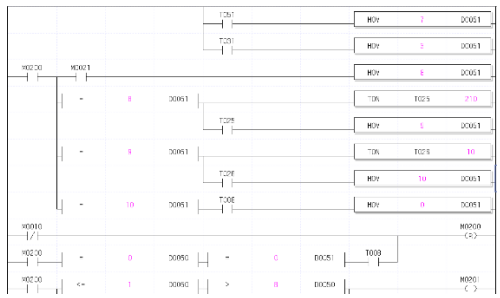

Figure 6: Ladder diagram of auto operation mode.

DISCUSSION

In this paper, integrated Vacuum and RF amp local controller has been presented. Integrated Controller provide automated process for amp and vacuum machine by PLC. Interlock function also realized by using plc module and HMI for integrated controller is also developed. Its HMI and integrated controller will be replaced from original two independent controller for machine stability and management of interlock. Development of integrated controller will be continuously expand to Low level RF controller.

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