DEVELOPMENT OF CONTROL SYSTEM FOR 10 MeV CYCLOTRON*

M. Hassani†, S.Y. Ghorashinejad, H. Afarideh
Faculty of Energy Engineering & Physics / AmirKabir University of Technology, Tehran, IRAN

Abstract

AmirKabir University of Technology is developing a 10 MeV cyclotron to produce radio isotopes. In order to operate the cyclotron stably, all sub-systems in the cyclotron are controlled and monitored consistently. The control system has been developed based on PLC and the operation is monitored by HMI permanently. Also, the control console located in the control room, provides data logging and controlling different steps of operation by the operator. In addition, the system can be remotely accessed over the network to monitor the status of cyclotron easily. The configuration of the control system for 10 MeV cyclotron will be presented in this paper.

OVERVIEW OF 10 MeV CYCLOTRON

The cyclotron accelerates the negative hydrogen particle to produce radioisotopes, and a couple of sub-systems make the particle acceleration possible. The cyclotron consists of cooling system, vacuum system, magnet system, ion source system, and RF system.

In order to accelerate the particle stably, it is necessary to fix the temperature and humidity of the environment. In addition, the order of vacuum inside cyclotron should be under 1×10^{-6} mbar. A double-stage high-vacuum system has been installed to improve the vacuum state. The cyclotron includes a panning ion gauge (PIG) type ion source for generating negative hydrogen from plasma by the use of arc power supply outside of cyclotron. The electromagnet field made by both RF system and magnet system accelerates the negative hydrogen for the desired energy level. The RF system is composed of two parts which are RF resonator and RF amplifier. The RF amplifier provides the high power RF signals to RF cavity to increase the dee voltage up to 50kV for electric field inside the cyclotron. The electric field is regulated by RF tuner. The average magnetic field is 1.71 T generated by about 143A coil current from magnet power supply (MPS) [1].

CONTROL SYSTEM DESIGN

The control system has access to each sub-system, and monitors the status of each device. In addition, the control system should set the proper parameters depending on the monitoring data from sub-systems, and prevent from the emergency situation occurred during the operation sequence of cyclotron. Therefore, we have carried out a requirement analysis starting from the system specification, and then designed the control system considering capability, expandability and accessibility to achieve high reliability and safety for the system [2].

The architecture of the control system consists of two parts; a host computer and a main control system (PLC). The main control system gathers the status signals of all sub-systems and supervises the whole cyclotron, comprehensively. Many parameters used in main control system, are shared with the host computer, so an operator can control the cyclotron through the host computer [3]. Each of sub-systems have a sub-program and interlock functions in PLC to protect them from unexpected damages. The primary specifications of 10 MeV cyclotron are shown in Table 1.

Table 1: Specifications of 10 MeV Cyclotron

System	Parameter	Specification
Magnet	Max/Min magnetic field	0.26/1.83 T
Ion source	Type	PIG
	H2 gas flow rate	0 ~ 10 SCCM
	Beam current	100 µA
RF	Frequency	71 MHz
	Dee voltage	50 kV
	Power	15 kV
Vacuum	Level of vacuum	1×10^{-6} mbar
Cooling	Water Temp.	20 ºC
	Water Resistivity	> 10 MΩ

Cooling System Control

The cooling system is a basis system with vacuum system for beam acceleration of cyclotron. The important parameters of cooling system are water temperature, resistivity, pressure, and flow. Therefore, the parameters are controlled in real time and consistently by different controllers which are installed in the chiller. PLC controls and monitors the status of cooling system by output analogue signals (4~20 mA) of chiller's controllers.

Vacuum System Control

The developing cyclotron has initial vacuum state (about 1×10^{-2} mbar) by using rotary pump, and then makes the high vacuum state (about 1×10^{-6} mbar) by using turbo-molecular pump. There are many valves such like roughing valve, fore-line valve, and main valve, between each vacuum pump and chamber. The vacuum level is measured by pirani and penning gauges. PLC receives the monitoring signals of vacuum status from gauges and controls the vacuum pumps and valves, simultaneously.

* Work supported by the Ministry of Science, Research and Technology of Iran.
† mojtaba.hassani@aut.ac.ir

ISBN 978-3-95450-167-0

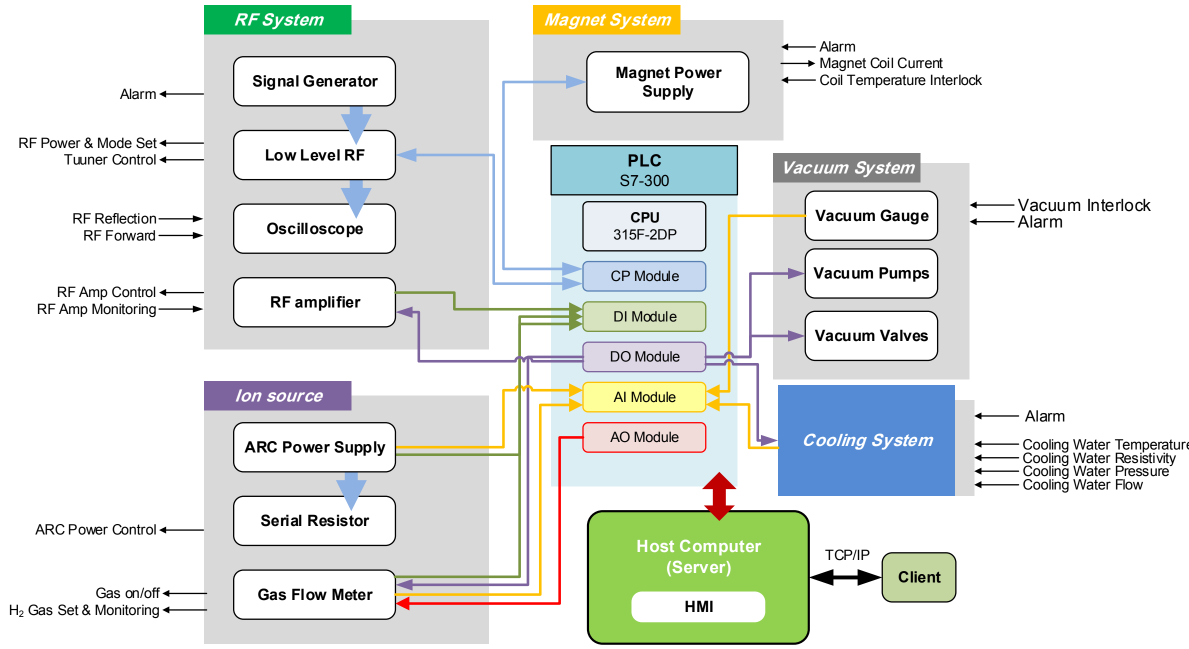

Figure 1: Architecture of 10 MeV cyclotron control system.

Magnet System Control

Magnet system is in charge of beam focusing and acceleration, and the magnet power supply (MPS) provides the current to electromagnet of cyclotron. The MPS includes control module based on FPGA, so that it can make the stability of provided coil current below 10ppm. Also, the magnet power supply can interface with main control system (PLC) through Modbus protocol. Therefore, PLC can access the magnet power supply and share the information about operation such like current value and interlock signals (over current, over heat, etc.).

RF System Control

The RF amplifier consists of pre-amplifier, intermediate power amplifier (IPA) and power amplifier (PA). The PLC can fulfil the sequence control with input and output signals for operation of RF amplifier. So, it can monitor the status of RF amplifier related to overload or interlock, and control the operation of RF amplifier.

The RF system also includes a Low Level RF (LLRF) to generate RF signal which is delivered to RF pre amp. The LLRF has internal oscillator, so that it can generate 71MHz RF signal by itself. It is also possible to receive the RF reference signal from external RF oscillator [4]. The PLC controls the RF power, RF mode (CW/Pulse), and RF duty (when the RF mode is pulse type). In addition, the LLRF can control the motor of RF tuner to regulate the resonant frequency of RF cavity. The main control system can access the LLRF by serial communication (RS485) and share the data.

Ion Source System Control

For the stable generation of negative hydrogen plasma, the ion source system needs hydrogen gas and high voltage at least 2 kV. Therefore, we adopted the gas flow meter for control the gas quantity constantly, and ARC power supply to provide high voltage/current to ion source. The gas quantity, passed from gas flow meter is 0~5V analogue signal which is monitored by PLC and monitoring system. This quantity can be set by PLC too. In addition, a 24 V digital signal (DIO) has been used for ON/OFF control of gas flow meter. The PLC can perform the control task and status monitoring of ARC power supply through a port on it.

IMPLEMENTATION

We implemented the control system by SIEMENS PLC as hardware platform and Totally Integrated Automation Portal (TIA Portal) as software to take into account the performance and convenience in use.

Hardware Platform Implementation

We have used SIEMENS PLC (CPU 315F-2DP) which has high performance as main control system. In addition, the platform is a modular type, so it is flexible.

Software Design

The control system software is classified into two programs; One is the program for main control system (real-time target), and the other is the program for host PC. The program for main control system performs control and data acquisition about operation of sub-systems. The data gathered by real-time target is exchanged with host computer program via TCP/IP protocol. The program for host computer includes the human machine interface (HMI) and the operator can control the cyclotron by this program. This HMI has been designed by WinCC in TIA Portal software.

Logging process data and alarms with WinCC Logging supports the acquisition and processing of process data from the cyclotron. An evaluation of the logged process

ISBN 978-3-95450-167-0

data then provides information on the operating status during the in process (production, processing, process etc.).

Process sequences can be documented, the capacity utilization or the production quality can be monitored or recurring fault conditions can be logged. Benefits of data logging are:

- Early detection of danger and fault conditions.
- Avoidance of downtimes by means of predictive diagnostics.
- Increase in product quality and productivity due to regular evaluation of log.

The values from external and internal tags can be saved in process data logs. In addition, data logging can also be triggered by events, e.g. when a value changes. WinCC Logging also lets us log alarms and document operational states and error states of the system.

Remote Control

The control system can be accessed remotely by the network clients via TCP/IP protocol. Using the web browsing program, one of the clients fully use the main control user interface provided by the host machine at a time.

Many tasks require special qualifications or are restricted by the process to special user groups. Carrying them out requires rights that are assigned to special user groups and users. WinCC (TIA Portal) supports the user in creating and managing user groups and users and in assigning the required rights in engineering and during runtime. The actual user can then be accepted in the user administration with a user name or user ID and password even during operation and then be assigned to a user group without any further changes to the configuration.

CONCLUSION

The 10 MeV cyclotron has a number of sub-systems. These sub-systems exchange the data of status with main control system. The main control system is implemented based on SIEMENS PLC (CPU 315F-2DP) which has high performance, so that the control system can perform the tasks for control and monitor the cyclotron with high reliability. The main control system communicates with host computer, and it is possible to control remotely via TCP/IP protocol.

REFERENCES

[1] R. Solhju *et al.*, "Design of 10 MeV Cyclotron Accelerator", *Iranian Journal of Physics Research*, vol. 15, pp. 225-234, 2015.

[2] J. Jacky *et al.*, "Control System Specification for a Cyclotron and Neutron Therapy Facility", in *Proc. PAC'91*, San Francisco, California, USA, May 1991, pp. 1359-1361.

[3] Y. S. Lee *et al.*, "The Development of Control System for 9 MeV Cyclotron", in *Proc. Cyclotrons'13*, Vancouver, BC, Canada, September 2013, paper TUPPT004.

[4] M. S. Sharifi Asadi Malafeh *et al.*, "New Approach in Design of Efficient Low Level RF Circuit for 10 MeV Cyclotron", *Iranian Journal of Physics Research*, vol. 15, pp. 235-242, 2015.

ISBN 978-3-95450-167-0