IMPROVEMENT OF RF CONTROL SYSTEM FOR THE 20 MEV PROTON LINAC OF PEFP

J. C. Yoon, J. Choi , J. W. Lee, and H. S. Kang

Pohang Accelerator Laboratory, POSTECH, Pohang 790-784, Korea

Abstract

This paper presents the improvement of RF control system for PEFP (Proton Engineering Frontier Project). The upgrade design is based on the use of VME based MODBUS/TCP Multi-function board connected to the specific low level RF Controllers (LLRF) via distributed I/O modules and Serial communication modules. The control system was based on EPICS (Experimental Physics and Industrial Control System) from the end of 2004. Starting from release 3.14, it is possible to run the EPICS database on VMEBUS hardware with UNIX operating system. Installation and commissioning of the RF module is scheduled on 2005. Control system to integrated the RF System to the PEFP control system is implemented. Hardware, software and various applications are upgrade to support the operation of RF Control system [1]. In this paper, we describe control structure and scheme of the current RF Control System and upgraded one.

INTRODUCTION

The RFQ (Radio frequency quadrupole) for PEFP has been built, which is a low energy accelerator for 3MeV proton beam. The required peak power of the cavity is 600 kW, and pulse width, repetition rate for initial operation is 100 us, 10 Hz respectively. To accelerate proton beam in the RFQ linear accelerator, The LLRF should have feedback control function of cavity field. The LLRF consists of a 350MHz signal generator, a 160W solid-state amplifier, amplitude/phase control loops, and RF interlocks. The designed field stability in the RFQ cavity is within $\pm$ 1% amplitude and $\pm 1.4^\circ$ phase using feedback control loops in the LLRF. For frequency control, another tuner controller module was used. The RF interlock signals comes from excessive reflected RF power, circulator arcs and window arcs [2]. The LLRF control requirements are cavity field control, cavity resonance control, RF & clock generation and distribution, and Master Oscillator generation and distribution. The control system now shows very stable and reliable characteristics enough to meet our control requirement. However, the control system is continuously being upgraded to accommodate additional control requirements such as the low level RF electronics. Part of the low level electronics were upgraded and replaced for enhanced performances of the phase feedback and automatic gain control loop, but the automatic phase-lock loop sowed some instability due to poor phase circuits, phase noises, and poor interface with control circuits. We use the EPICS tool kit as a foundation of the control system [3]. We developed RF control system for use VMEbus based

MODBUS/TCP Multi-function board. During the maintenance period, RF control system was upgraded. And control software was modified to support these changes. Application software for LLRF device and operator interface software are being developed. The overall development of the EPICS based upgrade RF control system, field installation, and integration test will be completed by the end of July 2005.
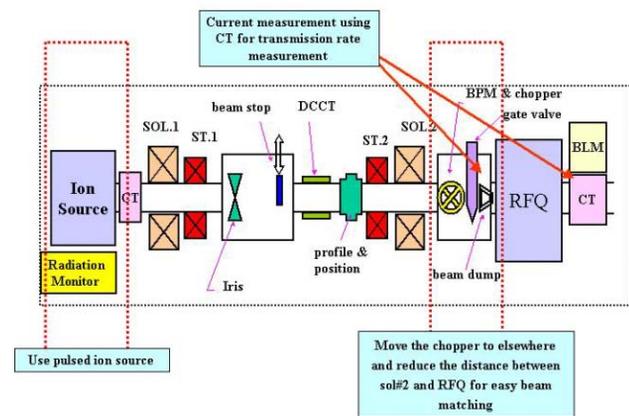

Figure 1: Structure of PEFP RFQ & DTL Devices [5].

SYSTEM UPGRADE

Some control requirements of the LLRF controller was changed to modify MODBUS/TCP protocol. After fiscal year 2004, we updated the MODBUS drivers occasionally for LLRF controller. One RFIOC (RF Input Output Controller) is control two LLRF controller (RFQ, DTL) by MODBUS/TCP. The structure of the upgrade RF control system is shown in Figure 2. The control system is 64bits VMEBUS based system. A PowerPC single board computer host module that is running the vxWorks real-time operating system. Control interfaces of the system consist of analog input/output, digital input/output, and MODBUS/TCP connections. As shown on Figure 3, the SCU (Signal Condition Unit) is used to RFIOC control the DTL station parameters. As mentioned above, we used MODBUS/TCP as the communication protocol. Modbus is the most widely used network protocol in the industrial manufacturing environment. MODBUS/TCP is a variant of the MODBUS family of simple, vendor-neutral communication protocols intended for supervision and control of automation equipment.

In general, each I/O signal corresponds to a Modbus address. For RF LLRFs, analog input/output and binary input/output signals are needed. We assigned addresses

1~10000 to binary output, 10001~20000 to binary input, 20001~3000 to analog input and 30001~40000 to analog output signals.
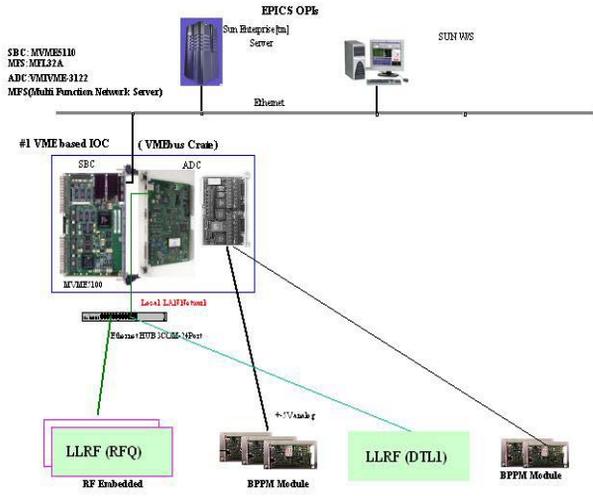

Figure 2: Structure of Upgrade RF Control System.
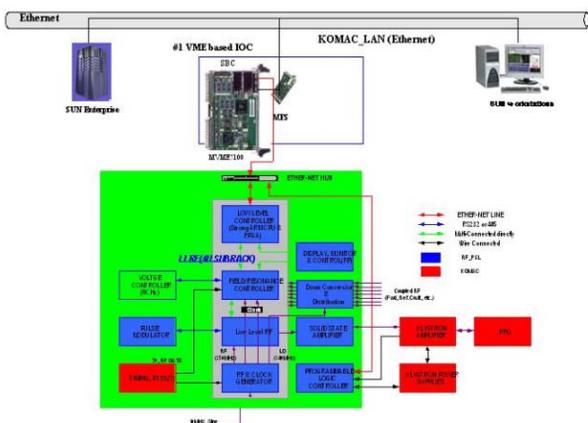

Figure 3: A picture of RFIOC & SCU.

Figure 4: Signal Flow from RFIOC to LLRF.

For each MODBUS address, a EPICS PV is given and the names are of type PE:XXX:XXXXX where XXX is control device type (LLR, DTL, VME) and XXXXX is device signal description. The total EPICS PV numbers are 406.

SOFTWARE UPGRADE

We have successfully upgraded the PEFP RF control system using EPICS. Control architecture was redesigned for efficiency and MODBUS/TCP protocol is used to simplify the development. By assigning a EPICS PV to a MODBUS address, we could easily determine the specifications of device drivers. We developed a set of device/driver support modules for the EPICS to support several network-based intelligent controllers, such as device In/Output module and SCU for Multi Function Server Board (MFLS32).The upgrade software consists of common driver module, a common device support module, and a device-specific module for each of devices (RFQ, DTL) to be support. We decided to implement the most basic common driver, which handles just sending a command and getting a response, with a method to allow us to implement beyond the basic at a higher layer in the device-specific modules. The essential part of device-specific modules is about constructing commands to be sent to a remote device, and parsing the response message, in addition to getting address information by parsing the link filed of the database record. The Common Driver Support module creates an message passing facility (MPF), for each communication server running on a remote device.

While the first version of the device/driver support are developed on R3.14.1 of EPICS on vxWorks [4], a recent trend toward Linux and multi-platform compliance of the latest version of R3.14.4, encouraged us to port the device/driver modules onto it. As shown on Figure 5, the porting of the upgrade RF control software
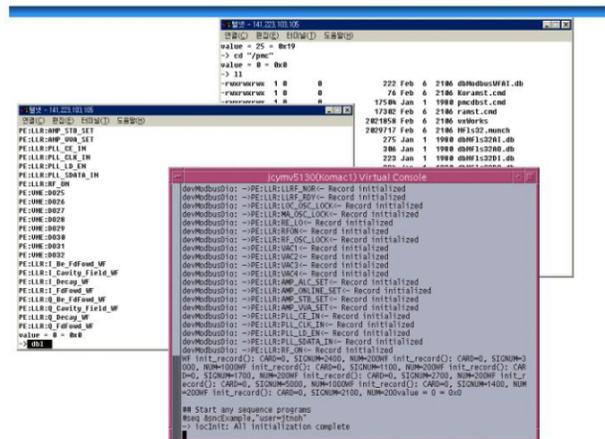

Figure 5: Porting of the upgrade RF control software.

User Interface

The new graph user interface software was designed based on one year of experience with a test running system. The host computer also serves a development environment for VxWorks, which is the operating system of IOCs. X-terminals are used as an operator interface in the RF control system. We currently use the version R3.14 of EPICS on this host machine. A test of the latest release of EPICS software, R.3.14 .4, is under way. The user interface of the PEFP RF control system two friendly graphic pages on the display screen of the control console. One is for the PEFP RF low-level system routine operation that includes system status and control parameters of the low-level system as shown in figure 6, improvement of EPICS Extensions of RF control system. The operator and machine engineer can fine tune and control the low level electronics of the PEFP RFQ & DTL system through this page. The other pages, display all the important parameters of Modbus network statutes, VMEbus analog & digital In/output values etc. The purpose of this pages display is focusing on global system status and debugging value RF IOC system.

Figure 6: Improvement of EPICS Extensions of RF control system.

CONCUSION

We are upgrading and modifying the RF control system to accommodate new control requirements and to apply long-term test experiences. Owing to the upgrade project of LLRF embedded controller, we have the chance to carefully examine and rebuild our intelligent Modbus client for LLRF subsystem. We have upgraded TCP Modbus firmware for multifunction network-based client board (MFLS32). The upgrade RF control system was installed EPICS IOC based and system control tested in March 2005.

REFERENCES

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